THE EFFECTS OF SIX HERBICIDES WITH A POTENTIAL FOR WILD-OAT CONTROL ON TEN DIRECT AND UNDERSOWN GRASSES

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Summary In three experiments six herbicides were applied at two doses to 10 grasses which had either been undersown in April or direct sown in August. The treatments were sprayed at two stages of growth after which visible effects on green material were measured.

Isoproturon caused severe damage to all grasses except when sprayed at 2.1 kg a.i./ha 8 weeks after cereal harvest. However, established Cock's-foot cv S.37 was notably resistant. High doses of difenzoquat (3.0 kg a.i./ha) damaged all grasses even when established, while ethofumesate (5.0 kg a.i./ha) checked establishing grasses sown in August. None of the other herbicides affected the Perennial and Italian Rye-grasses. Timothy cv S.352 was most susceptible, especially to the herbicides applied at high doses. Cock's-foot cv S.37 was damaged by all high dose applications except flamprop-isopropyl, and by normal doses of ethofumesate and benzoylprop-ethyl, especially at tillering. Meadow fescue cv 'Rossa' was particularly susceptible to the high dose of ethofumesate applied at tillering.

Spring Barley cv 'Mazurka' was damaged by ethofumesate and by high doses of all the other herbicides.

Résumé Dans 3 essais 6 herbicides ont été appliqués à 2 doses différentes dans 10 espèces de graminées semées sous couvert en avril ou sans couvert en août. Les pulvérisations ont en lieu à deux stades de croissance différents et ensuite une évaluation visuelle de la matière verte a été réalisée.

L'isoproturon a provoqué de graves dégâts chez toutes les graminées sauf dans des pulvérisations à 2.1 kg m.a./ha 8 semaines après la moisson de la céréale. Cependant le dactyle (var. S.37) s'est montré nettement résistant. Des doses élevées du difenzoquat (3.0 kg m.a./ha) ont nuit à toutes les graminées, même bien établies, tandis que l'éthofumesate (5 kg m.a./ha) a provoqué un ralentissement de végétation dans les graminées semées en août qui étaient en voie de s'établir. Aucun autre herbicide n' a affecté le ray-grass anglais ni celui d'Italie. La fléole des prés (var. S.352) était l'espèce la plus sensible, surtout aux herbicides appliqués à dose élevée. Le dactyle (var. S.37) a subi des dégâts suivant toutes les applications à dose élevée, sauf dans le cas du flamprop-isopropyl, et suivant des doses normales de l'éthofumesate et du benzoylprop-ethyl, surtout a l'époque du tallage.

L'éthofumesate, ainsi que les doses élevées de tous les autres herbicides, a provoqué des dégâts dans l'orge du printemps (var. Mazurka).

INTRODUCTION

Wild-oats are a serious problem in many herbage seed crops grown in Great Britain. The low level of contamination permitted in the European Economic Community has increased the need for reliable control.

Several Wild-oat herbicides have already been evaluated on grasses sown without a cover crop in the Spring (Oswald and Haggar, 1974). However, little is known of the tolerance of undersown or autumn direct sown grasses to these herbicides. Hence, three experiments were set up involving 6 herbicides each applied at two doses, applied at two growth stages to 10 popular grasses on a sandy loam soil at Begbroke Hill, Oxford. In two experiments the grasses were undersown in spring barley in April. In the third experiment the grasses were direct sown in August. All effects were assessed as scores of reductions in green material.

METHOD AND MATERIALS

The grasses and herbicides used were the same in all three experiments. These are shown in Table 1.

Table 1

The grasses and herbicide treatments

Grass		Seed rate kg/ha	Herbicide	Dose (kg a.i./ha)
Perennial Rye-grass	cv S.24	15.7	Isoproturon	2.1 & 6.3
" "	cv 'Gremie'	"	Difenzoquat	1.0 & 3.0
" "	cv 'Barlenna'	"	Flamprop-isopropyl	1.0 & 3.0
" "	cv S.23	"	Chlorfenprop-methyl	4.75 & 14.25
" "	cv 'Taptoe'	22.4	Ethofumesate	1.68 & 5.0
" "	cv 'Barpastra'	"	Benzoylprop-ethyl	1.12 & 3.36
Italian Rye-grass	cv RvP	16.8		
Timothy	cv S.352	9.0		
Cock's-foot	cv S.37	11.2		
Meadow fescue	cv 'Rossa'	15.7		

Dates of drilling and spraying are shown in Table 2.

Table 2

Dates of grass drilling and herbicide spraying

	Date drilled	Date sprayed	
Experiment 1	5 April 1974	8 May 1974	22 May 1974
Experiment 2	"	21 August 1974	10 October 1974
Experiment 3	23 August 1974	11 October 1974	22 April 1975

A plaid design of two replicates was used in each of the 3 experiments, with the grass varieties as main plots.

For experiments 1 and 2 Spring Barley, cv 'Mazurka', was drilled on 3 April 1974. For each of the 3 experiments the 10 grasses were drilled separately in plots 22.5 m x 2 m using an Oyjord seed drill. The plots were later rolled.

Each herbicide was sprayed at two doses: that normally used for Wild-oat control in cereal crops and 3 times greater. The high dose was applied to indicate the possible effects of over-lapping with spray boom or adding more than the required amount of concentrate.

The treatments were applied in 1.5 m strips at right angles across the grass rows. Thus the area of each grass sprayed with each treatment was 2 m x 1.5 m. All spray treatments were applied using an Oxford Precision Sprayer fitted with Tee jets. Volume rate was 336 l/ha and pressure 2.07 bars.

The growth stages reached by the grasses at spraying are shown in Table 3.

Table 3

Growth stages of the grasses at spraying

Grass variety	Experiment 1 1974 8 May	Experiment 1 1974 22 May	Experiment 2 1974 21 Aug 10 Oct	Experiment 3 1974 11 Oct	Experiment 3 1975 22 April
Perennial Rye-grass	2-3 leaves	1-5 tillers	Well-tillered	1-5 tillers	Well-tillered
Italian "	2-3 "	1-4 "	"	1-5 "	"
Timothy cv S.352	1-2 "	3-4 leaves	"	2-3 leaves	"
Cock's-foot cv S.37	1-2 "	4-5 "	"	2-3 "	"
M. fescue cv 'Rossa'	2-3 "	1-2 tillers	"	2-3 "	"

After spraying, treated plots were compared to unsprayed controls for the amount of green material present. If no green material was visible a score of 0 was given. If the amount of green material was equal to that on unsprayed control plots then a score of 9 was given. Intermediate effects were scored between 0 and 9. Each plot was scored by two people independently and the mean of the two scores was recorded.

In experiment 1 the effects on grasses could not be assessed until the barley crop had been harvested.

An application of a commercial mixture of ioxynil and mecoprop at 8.4 l/ha was made on 31 May 1974 over the whole undersown experiment area to control the broad-leaved weeds present.

A commercial mixture of bromoxynil and ioxynil at 2.1 l/ha was applied on 17 March 1975 to control broad-leaved species present on the area which had been direct sown the previous August.

RESULTS

Experiment 1 Undersown Grasses Sprayed In Spring

Effects of herbicides at normal doses (Fig. 1a)

a) Applied at early growth stage:

None of the grass varieties was damaged by difenzoquat, chlorfenprop-methyl, ethofumesate or benzoylprop-ethyl. Flamprop-isopropyl reduced S.352 Timothy by 20%. Isoproturon severely damaged all grasses although S.37 Cock's-foot had recovered 40 days after spraying.

b) Applied at later growth stage:

Herbicide effects on tillering plants were similar to those on younger plants except that S.37 Cock's-foot suffered a 20% reduction after treatment with ethofumesate, although the effect was transitory. The effects of isoproturon were still damaging but not as severe as earlier. S.37 Cock's-foot was completely resistant to this herbicide.

c) Effects on 'Mazurka' Spring Barley:

Only ethofumesate at both dates and benzoylprop-ethyl at the later date caused any lasting damage.

Effects of herbicides at 3 x normal doses (Fig. 1b)

Most of the above mentioned effects became more exaggerated as the dose was increased, while some of the other herbicides became phytotoxic. For instance, difenzoquat checked Rye-grass slightly, and S.37 Cock's-foot and 'Rossa' Meadow fescue moderately, when applied at the tillering stage; S.352 Timothy was reduced by up to 80%. Also, chlorfenprop-methyl caused reductions of 40% to S.352 Timothy at the 1-2 leaf stage and to S.37 Cock's-foot at 4-5 leaves.

Moderate damage to 'Mazurka' Spring Barley followed all applications, especially at the second growth stage of the grasses.

Experiment 2 Undersown Grasses Sprayed After Cereal Harvest

Effects of herbicide at normal doses (Fig. 2a)

a) Applied 5 days after harvest:

Difenzoquat, flamprop-isopropyl, chlorfenprop-methyl, ethofumesate and benzoylprop-ethyl only caused slight checks to S.352 Timothy and S.37 Cock's-foot. But isoproturon caused severe reductions of all grasses, although S.37 Cock's-foot had recovered 40 days after spraying.

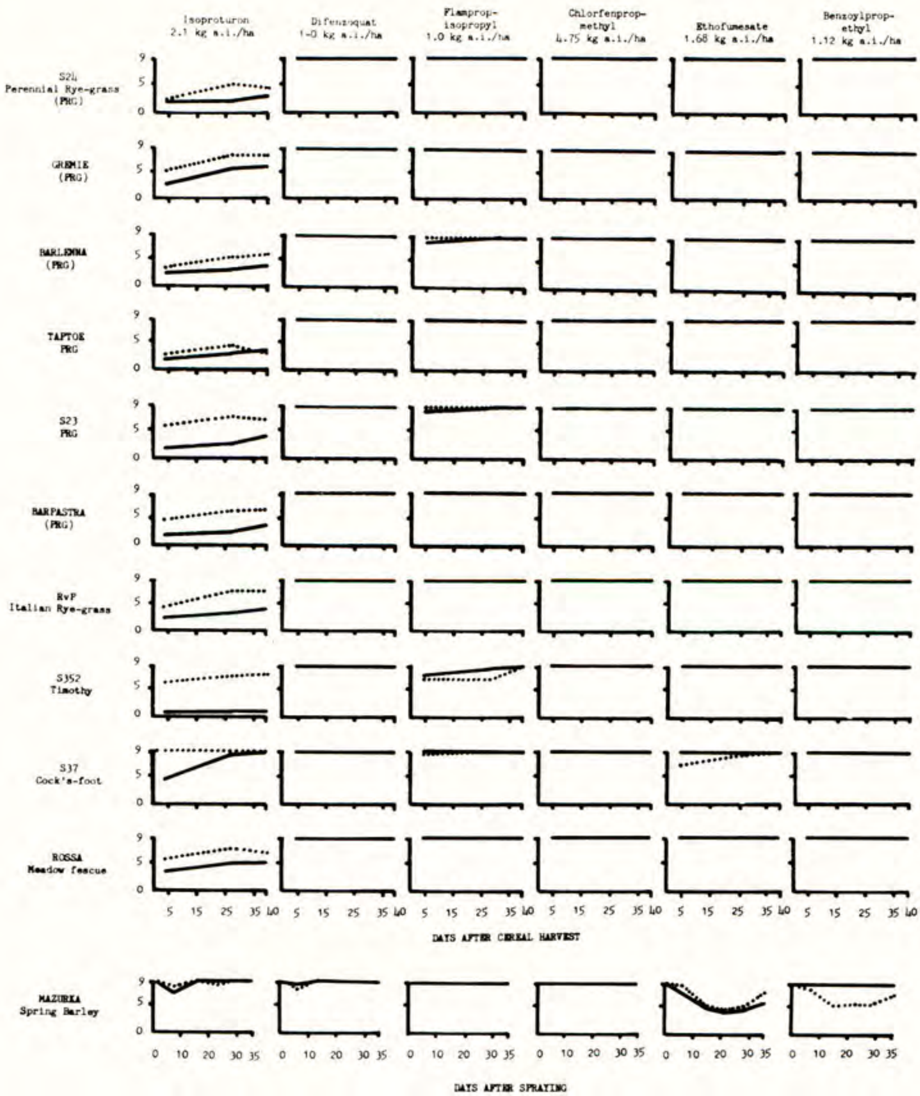
b) Applied 55 days after harvest:

Apart from a slight check to S.352 Timothy by difenzoquat, none of the herbicides damaged any of the grasses.

Effects of herbicide at 3 x normal doses (Fig. 2b)

Reductions in all grasses were again severe following isoproturon sprayed soon after cereal harvest. The later application also caused general damage but was less severe. S.352 Timothy and S.37 Cock's-foot were seriously affected by all herbicides whereas the other grasses remained relatively unaffected.

Fig. 1a. Normal doses of 6 herbicides at 2-3 leaf (——) and tillering (····) stages.
Effects on green material scored 0 (absence) to 9 (equal to unsprayed control).



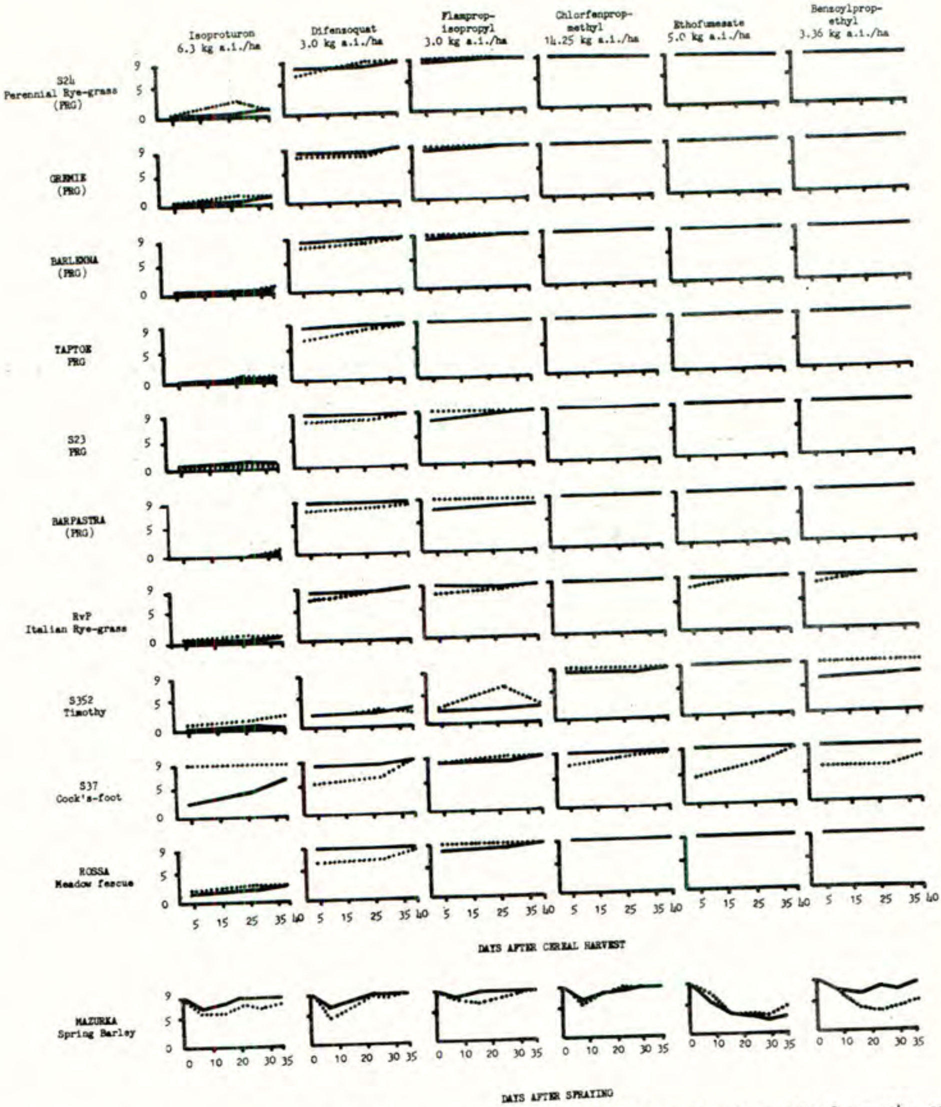
Experiment 3 Autumn Direct Sown Grasses Sprayed In The Autumn And Spring

Effects of herbicides at normal doses (Fig. 3a)

a) Applied in the autumn:

The Rye-grasses were resistant to all herbicides except isoproturon. Only S.37 Cock's-foot was moderately resistant to this chemical. There were brief checks

Fig. 1b. High doses of 6 herbicides at 2-3 leaf (——) and tillering (····) stages.
Effects on green material scored 0 (absence) to 9 (equal to unsprayed control).

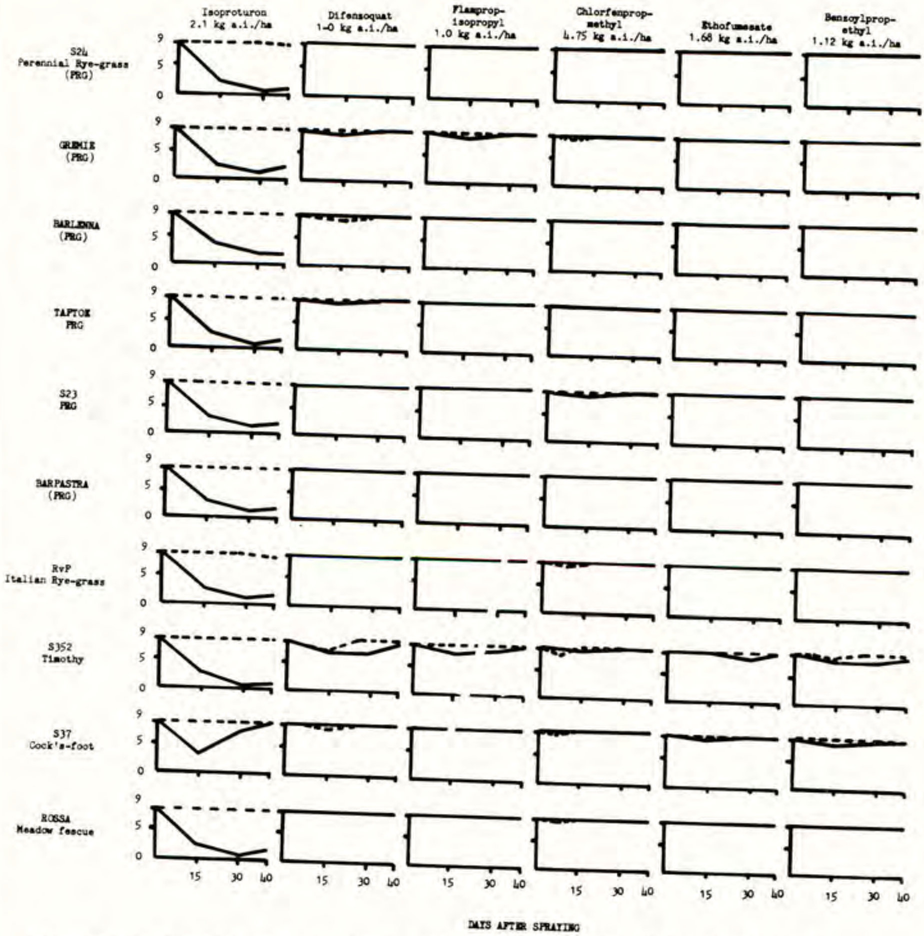


after difenzoquat and flamprop-isopropyl on S.352 Timothy and after ethofumesate and benzoylprop-ethyl on S.37 Cock's-foot.

b) Applied in the spring:

Isoproturon was not as damaging as in the autumn. S.37 Cock's-foot had completely recovered 25 days after spraying. Unlike the autumn application S.352

Fig. 2a. Normal doses of 6 herbicides sprayed 5 days (____) and 55 days (----) after cereal harvest. Effects on green material scored 0 (absence) to 9 (equal to unsprayed control).



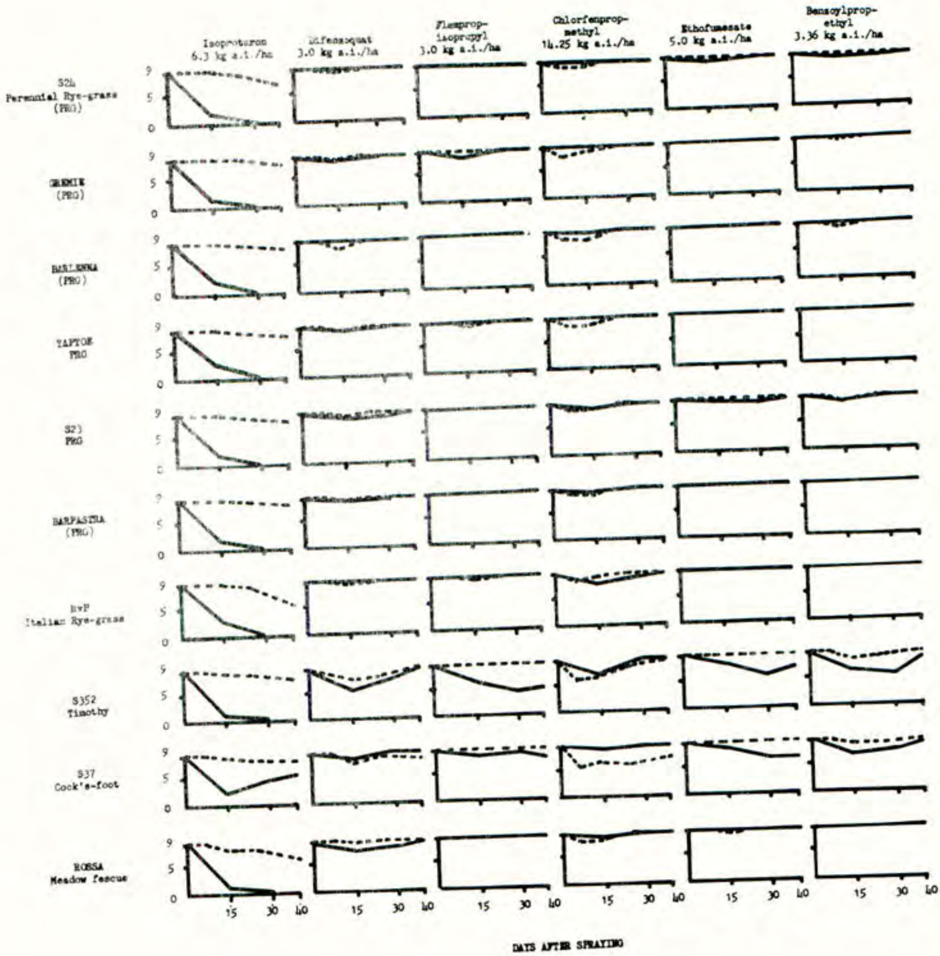
Timothy was damaged by benzoylprop-ethyl. However, S.37 Cock's-foot was resistant to ethofumesate at this time.

Effects of herbicides at 3 x normal doses (Fig. 3b)

All Rye-grasses and 'Rossa' Meadow fescue were resistant to flamprop-isopropyl and benzoylprop-ethyl sprayed in either autumn or spring. Difenzoquat and chlorfenprop-methyl in the autumn and ethofumesate in the spring were also harmless. But S.352 Timothy and S.37 Cock's-foot were damaged by all these treatments.

Ethofumesate in the autumn slightly checked all Rye-grasses except RvP Italian Rye-grass. The other grasses were severely damaged. Spring applications of difenzoquat and chlorfenprop-methyl caused general slight damage. Isoproturon was extremely damaging to all the grasses although S.37 Cock's-foot showed some resistence in the spring.

Fig. 2b. High doses of 6 herbicides sprayed 5 days (——) and 55 days (----) after cereal harvest. Effects on green material scored 0 (absence) to 9 (equal to unsprayed control).

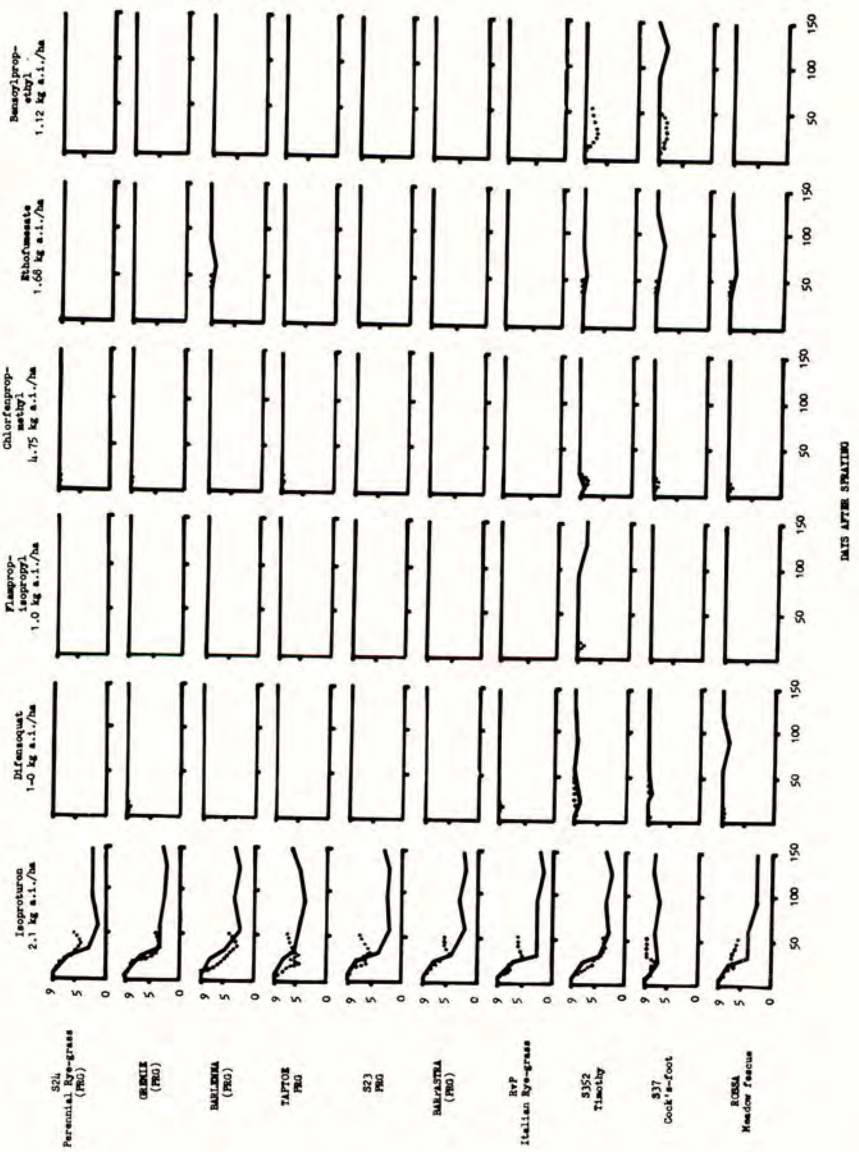


DISCUSSION

The results indicate that all herbicides, except isoproturon, can be used safely in Rye-grass seed crops, although care must be taken not to exceed normal doses of difenzoquat or ethofumesate. However with Timothy, Cock's-foot and Meadow fescue greater caution must be taken when considering which herbicide to use; all proved more susceptible than the Rye-grasses.

All the herbicides, except ethofumesate, are potentially useful in undersown grass crops. However, exceeding the normal dose should again be avoided as high doses did damage the cereal crop.

Fig. 3a. Normal doses of 6 herbicides sprayed in Autumn (——) and Spring (····) on grasses sown in August. Effects on green material scored 0 (absence) to 9 (equal to unsprayed control.)



As these results only indicate the visible effects of spraying the six herbicides on the ten grasses established in normal situations and since no assessment was made of the effects on vegetative yield, fertile tiller production and seed yield, these preliminary screening experiments need to be complemented by further seed production investigations on a wider range of soil types and climatic conditions before firm conclusions on crop safety to these herbicides can be made. However a brief guide to the susceptibility of the grasses to the herbicides is given in table 4.

Fig. 3b. High doses of 6 herbicides sprayed in Autumn (——) and Spring (....) on grasses sown in August.
Effects on green material scored 0 (absence) to 9 (equal to unsprayed control.)

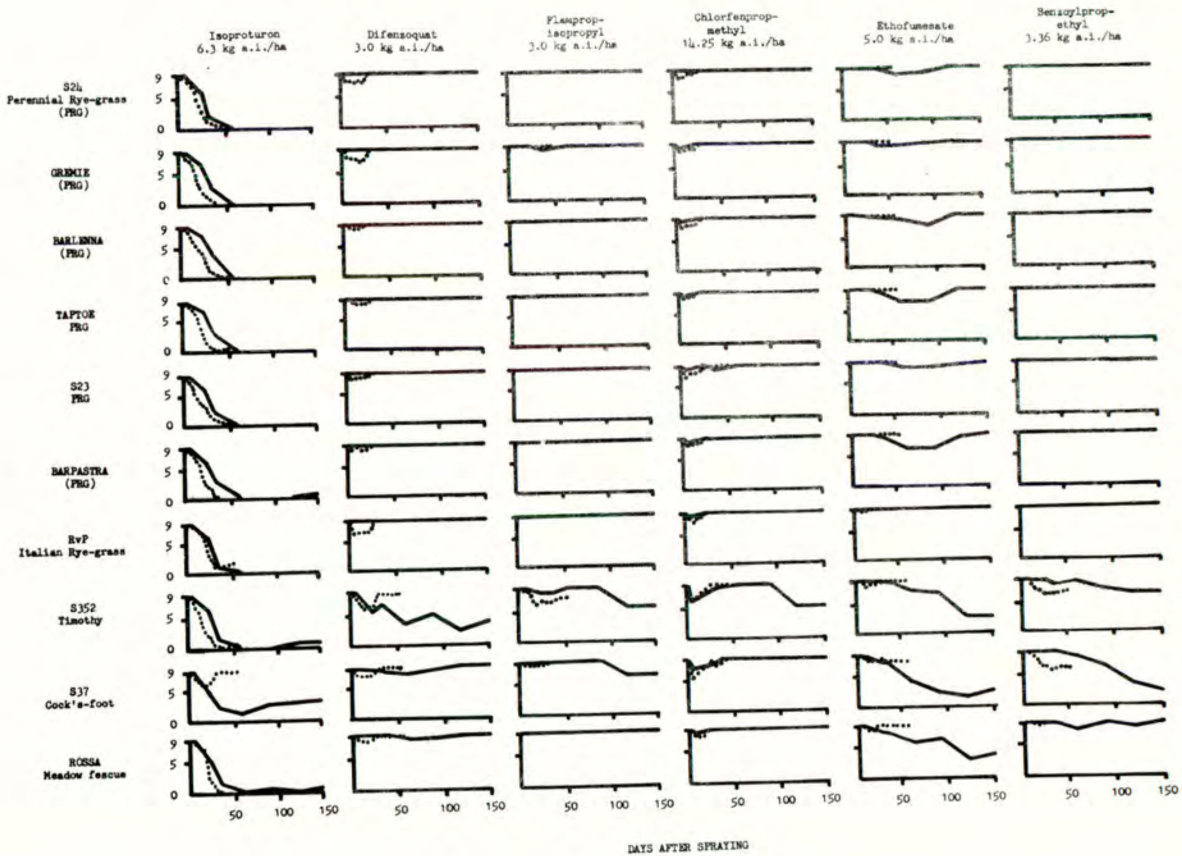


Table 4

Susceptibility of the grasses at three stages of growth to the herbicides sprayed at normal doses

Grass Variety	Isoproturon 1	2	3	Difenzoquat 1	2	3	Flamprop-isopropyl 1	2	3	Chlorfenprop-methyl 1	2	3	Ethofumesate 1	2	3	Benzoylprop-ethyl 1	2	3
S.24 (PRG)	S	S	MS	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Gremie "	S	MS	MS	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Barlenna "	S	S	MS	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
S.23 "	S	MS	MS	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Taptoe "	S	MS	MS	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Barpastra "	S	MS	MS	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
RVP (IRG)	S	S	MS	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
S.352 Timothy	S	MR	MS	R	R	MR	R	MR	R	R	R	R	R	R	R	R	R	MR
S.37 Cock's-foot	MR	R	MR	R	R	R	R	R	R	R	R	R	MR	MR	R	MR	R	R
'Rossa' M.fescue	S	MS	MS	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R

KEY TO SYMBOLS

Susceptibility

S = Susceptible - Scored 0, 1 and 2
MS = Moderately susceptible - Scored 3, 4 and 5
MR = Moderately resistant - Scored 6 and 7
R = Resistant - Scored 8 and 9

Stage of Growth

1 = 2-3 leaves
2 = Just tillering
3 = Well tillered

Acknowldegements

I wish to thank Messrs F W Kirkham and C J Bastian for assistance with the experimental work and to R J Dale and the WRO Farm Staff for their co-operation in site preparation. I am also grateful to Dr R J Haggar for helpful criticism of this paper. The supply of seed by Twyford Seeds Ltd I also acknowledge.

References

OSWALD, A.K. and HAGGAR, R.J. (1974) The tolerance of ten grass varieties to six herbicides with a potential for Wild-oat control in herbage seed crops. Proc. 12th British Weed Control Conf., 715-722

THE INFLUENCE OF CHANGING HUSBANDRY ON WEEDS AND WEED CONTROL IN ARABLE CROPS

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Systems of arable husbandry have changed over the past 25 years or more, that much would be difficult to deny. However, the present state of agriculture is characterised by continued and continual change rather than change from one stable or relatively stable system to another. This makes it rather difficult to attribute changes in weed problems to changes in husbandry when neither can be critically defined. The purpose of this paper is therefore twofold. First to review changes in weeds and their control where these have been reliably recorded or can be intelligently discussed. Secondly, to attempt to discern any sign of a re-stabilization. That is, a return to relatively constant sequences of cropping and cultivations which, in turn, lead to relatively consistent problems and possibilities for weeds and weed control. First what aspects have changed and what can we say reliably about the effects of these changes on weeds.

Rotation

One of the most obvious changes over the past 25 years has been the increasing tendency for farmers to grow cereal crops in succession. At first this move to continuous cereal growing was confined to spring sown barley but now, increasingly, the trend is to continuous or near continuous winter wheat. We cannot assume that this trend is easily reversible, economic pressures continue to favour wheat growing and some of the possible alternative crops are not suited to our heavier soils. This intensification of cereal growing is at one extreme of the agricultural scene. At the other is an intensification of the cultivation of row crops and certain vegetables on large farms in certain favoured regions.

Unfortunately there is little critical information on the effect of rotation on weed populations. However, we can reasonably blame the decline in the use of rotations for many of our problems. The grass weeds of cereals, for generations, have been associationed with increased intensivity of cereal growing. Wild beet, our newest weed has become most serious in areas of Belgium, France and England with short rotations in which sugar beet appears frequently. Weed potatoes, are also associated with certain rotations. Our colleagues in the Netherlands (Lumkes, 1974) alarm us with reports of areas of land growing potatoes one year in two theoretically. In fact such land is growing potatoes every year, for the intervening crops of sugar beet and cereal are heavily infested with potatoes as weeds.

It does seem, therefore, that abandoning rotation or even reducing the length of rotation of certain crops has exacerbated some weed problems. In many cases a return to more traditional rotations may be totally impractical. However, if this were possible, would it be helpful, is this something that can be recommended to the farming community with any confidence? The answers must be mixed. In some instances, of course, rotational crops could be of great value. Oilseed rape in predominantly cereal rotations has already shown itself to be an extremely useful crop, in helping to control grass weeds. Grass leys are quite clearly of assistance in suppressing wild-oat and blackgrass populations. However rotation is not a panacea and some general points must be made. First, rotation is no longer only a cultural method of weed control. The value of oilseed rape, which was noted earlier, arises mainly from the fact that carbetamide, propyzamide and dalapon are available for use in this crop and can give excellent control of wild-oats and blackgrass so the rotational value is purely herbicidal and not cultural. From our point of view one is not so much looking for 'break crops' as for crops, profitable in their own right, in which a high degree of weed control is somewhat easier to achieve, usually with herbicides, than in cereals. Secondly, rotation is not an unmixed blessing so far as weeds are concerned. The benefit of grass leys in reducing populations of wild-oats and blackgrass has been noted. However, unless leys are managed extra-ordinarily well they can build up populations of the couch grasses, thus exchanging one problem for another (Cussans, 1973).

The grave problem of volunteer crops is in a sense a product of rotation. A recent example of the importance of this occurred when there was considerable interest in alternating the growth of winter wheat and spring barley. This was an excellent idea from the disease point of view and allowed easier control of wild-oats and blackgrass but it was, for many farmers at least, completely killed by the problem of volunteer barley in the wheat when the latter was established by minimum tillage.

Tillage

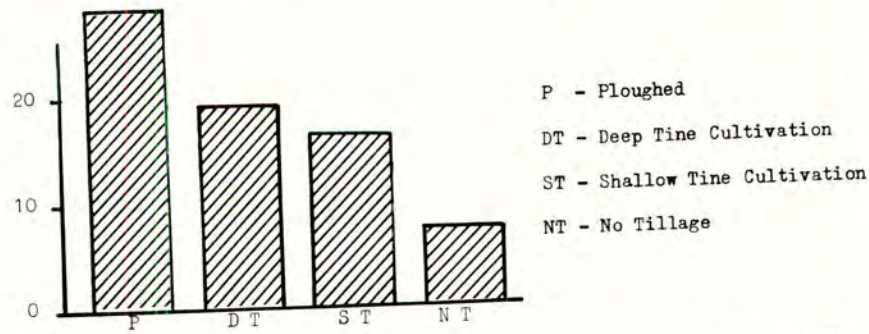
There have been two major changes in the use of cultivations. Within the life of crops there is now very much less interrow cultivation than was normal until a short time ago. Between crops, the move to reduced cultivation was slower. The area of crops direct drilled, with no cultivation at all, has increased very markedly although it was still small at 137,000 ha in 1974 (Allen, 1975). There are no reliable data on the extent to which intermediate non-ploughing techniques are used. However, in many regions a very high proportion of the cereal acreage is established following tine cultivation.

This subject must be dealt with in some detail partly because there is probably more information on the effect of tillage on weeds than some of the other factors we are considering and partly because this paper includes presentation of a research report on this subject (Pollard and Cussans, 1976).

Fig. 1

The response of annual broad-leaved weeds to cultivation

Total seedlings/m^2 - Mean of 5 years at Begbroke



A number of experimenters (Bacthaler, 1974; Cussans, 1966, 1975; Jones, 1966) have recorded that with reduced cultivation there are fewer seedlings of annual dicotyledonous weeds. Figure 1 shows a summary of this effect from a recent WRO/

Letcombe joint tillage experiment (Pollard and Cussans, 1976). There was a progression from ploughing to deep tine cultivation to shallow tine cultivation to direct drilling with weed populations on the ploughed exceeding those on direct drilled plots by a considerable margin. I think we have to say that this effect was to some extent of academic interest only. We sprayed all of these plots and we felt that most farmers would have felt constrained to do the same so no economic benefit was gained from this reduction in weed numbers, although one assumes there must be some longer term effects. Even in this regard it was surprising that the magnitude of the difference between the different cultivation treatments did not vary very much and certainly did not vary continuously during the life of these experiments.

Table 1 shows the ratios between weed populations on ploughed plots and on direct drilled plots recorded year by year over a number of years. One might have expected that either the relative numbers of weeds on ploughed plots would have increased continually or the lower numbers on direct drilled plots would have decreased continually but in fact the ratios showed no consistent trend. The weed populations were behaving as though there were inexhaustable reserves of weed seeds which, throughout the course of these experiments, showed a fairly consistent response to cultivation. This may indeed be a fair reflection of the state of affairs for these broadleaved weed species are generally of far greater persistence than the grass weed species which are referred to later. Some broad-leaved weeds did not follow the general trend, notably chickweed (Stellaria media) and the 'may-weeds'.

Table 1

A comparison of weed populations on ploughed and direct-drilled plots over a period of five years at Begbroke

Ratio of numbers of dicotyledonous seedlings. $\frac{\text{Ploughed plots}}{\text{direct drilled plots}}$

	All spp.	Polygonum spp.	Brassiceae
1969	6.3	23.2	3.5
1970	3.7	6.9	
1971	3.5	4.4	6.4
1972	4.0	37.6	9.7
1973	3.6	22.0	7.0

The second general observation has been that any departure from traditional mouldboard ploughing has generally led to a considerable increase of annual grass weeds. These include, the meadow grasses, Poa annua and Poa trivialis, blackgrass Alopecurus myosuroides, wild-oats Avena spp., volunteer cereals and sterile brome, now variously called Bromus sterilis or Anisantha sterilis. All of these species have been recorded in greater profusion on reduced cultivation treatments.

The work on populations of A. fatua in spring barley shows that this response to cultivation is not simple. We have described elsewhere the increased natural mortality of Avena fatua seed from stubbles which remain undisturbed compared with land which is cultivated soon after cereal harvest. This work suggested that direct drilling of spring barley should lead to reduced populations of Avena fatua and this has been confirmed experimentally (Wilson, 1972, Wilson and Cussans, 1972). However the experience on the WRO/Letcombe joint tillage project did not support this; in most cases there were more plants of Avena fatua on direct drilled plots than on ploughed, (Table 2).

Table 2

The effect of cultivation system on A. fatua populations

A. fatua populations ÷ numbers on ploughed plots	N.T.	S.T.	D.T.
Begbroke 1973	0.5	0	5.5
Buckland 1973	5.8	3.0	4.8
1974	8.2	4.2	3.5
1975	4.4	6.4	6.2

We considered that two quite separate factors were involved in this discrepancy. First the tillage experiments summarised in Table 2 were concerned with populations where the buried seed of Avena fatua greatly exceeded the more recently shed seed so therefore the autumn mortality was of correspondingly low relevance. The second factor was that early emerging wild-oats were able to survive on the direct drilled plots, which were not subjected to seedbed cultivations in spring. Other work has shown that this early emerging fraction of the population is the fraction which is at the greatest competitive advantage. The data from the WRO/Letcombe project did confirm the earlier conclusions that tine cultivation encouraged more seedlings of A. fatua than mouldboard ploughing from a given level of soil seed reserves.

With winter sown cereals there is another complication. We have shown that the autumn germinating fraction of wild-oat populations, Avena fatua as well as Avena ludoviciana forms the potentially most serious source of competition to the crop and of formation of new seed. Therefore anything which increases the number of autumn emerging seedlings of wild-oats can be of profound significance even if the total seedling population is not affected. This autumn germination appears to be mainly of recently shed seeds, so that the age structure of the population is important here, as with spring cereals.

Table 3

Germination of Avena fatua in the autumn: four experiments in Oxfordshire and Wiltshire

	Autumn seedlings/m^2		
Expt. 1	Stubble cults.		No stubble cults.
Straw burnt	350		102
Not burnt	141		31
Expt. 2			
Straw burnt	12		4.8
Not burnt	8.4		2.4
Expt. 3	Cults to 4"	Cults to ½"	No cults.
Straw burnt	12	34	0.7
Not burnt	2	3	0.2
Expt. 4			
Straw burnt	16	13.5	1.0
Not burnt	2	0.7	0.2

Table 3 shows some effects of stubble cultivation and straw treatment on autumn emergence of A. fatua which have been published elsewhere (Wilson and Cussans, 1975) and some previously unpublished data. There were more autumn seedlings on cultivated plots and on plots where straw had been burned and these two factors have interacted. Although burning has reduced seed number it has reduced dormancy of the seed which survived and has in fact increased seedling number. This is a complex and intriguing subject in itself but one we cannot really develop further here. In general one can only reiterate that any departure from mouldboard ploughing has generally resulted in more annual grass weeds.

One other group of weeds which are known to respond to tillage are the perennials. Generally speaking, the less cultivation the more these weeds flourish. We have observed Trifolium repens, wild white clover, as a weed and other perennials favoured by reduced cultivation as well as couch grass Agropyron repens which is the obvious example. Table 4 shows the results of one experiment on A. repens and illustrates the dramatic effect of direct drilling.

Table 4

Cultivation and A. repens

Cropped with Spring barley, treated from 1970

		July 1971	July 1972
Nil	Nil	23	246
Rot. cult.	Nil	7	46
Nil	Plough	4	17
Rot. cult.	Plough	0.4	0.4

Tillage within crops affects weeds and is itself a form of weed control. In many crops over the past few years a sequence of events has occurred where the use of herbicides permits abandonment of interrow cultivation. This in turn permits reduced row widths, broadcast bed systems and so on but this in turn permits development of resistant weeds which are then extremely difficult to control because the broadcast bed narrow row system does not allow interrow cultivation or weeding.

Finally, an aspect of tillage, which may be of extreme importance, concerns not the weeds but the herbicides. It is established that soil cultivation, preferably ploughing, is desirable to disperse residues of certain persistent soil herbicides. This can disrupt a system based on reduced cultivation. The classic example of this occurs with potatoes. Ploughing is necessary to disperse residues of metribuzin but non-ploughing is the best way to reduce survival of groundkeeper potatoes. Herbicides used in sugar beet and oil seed rape also suffer from this limitation. With these crops, ploughing is commonly considered necessary anyway to bury crop residues. However it may be that, by burying seed, ploughing prolongs the life of the shed rape or annual wild beet seed. This could be extremely serious, even if populations were reduced in the short term by ploughing, but it must be said that this is largely surmise at the moment.

Plant arrangement

One obvious example of plant arrangement, reduced row spacing for certain crops, has been discussed. With cereal crops, row width has altered slightly over the years but more important there is currently a tendency to reduce plant population. Professor Laloux, whose system has been widely publicised recently, recommends a maximum population for wheat of 200 or so plants per square metre and other sources have tended to support this. My colleague, Wilson and I have shown quite clearly with spring cereal crops that any reduction in cereal plant population, even though this may not reduce yield in the absence of weeds, will allow considerably increased development of weeds. Table 5, taken in abridged form from Cussans and Wilson, 1975, demonstrates the effect on A. repens rhizomes and A. fatua seed production of reducing populations of spring barley. We have not so far worked with winter wheat but it would be remarkable if a similar result did not occur. I think we must say that any reduction in crop populations must always be accompanied by extremely good, preferably pre-emergence, weed control, otherwise increase in weed vigour is likely to nullify any advantages.

Table 5

The effect of varying seed rate of spring barley on the growth of Agropyron repens and Avena fatua

Seed rate	1969	1970	1971
		A. repens new rhizome g/m^2	
90 kg/ha	1.7	27	79
180 "	0.3	14	54
		A. fatua seeds/m^2	
90 kg/ha	3063	3439	1059
180 kg/ha	1971	2050	1378

Herbicide use

There has been much discussion of the development of the weed flora over the last 25 years or so to the advantage of species resistant to the most commonly used herbicides. Many observers have noted that the charlock Sinapis arvensis, and poppy of the 1940's gave way to the cleavers Galium aparine and knotgrass Polygonum aviculare of the 1950's, and these in turn have given way to the current problems with grass weeds. Since most of the grass weeds are favoured by modern systems of cultivation as well as being difficult to control with herbicides, we must expect their dominance to continue.

Recently there have been suggestions that we may be seeing development of the flora to the advantage of resistant strains of weeds within species normally susceptible to herbicides. It is possible that such a development could be linked to other cultural factors. The greatest safeguard against the rapid development of herbicide resistance was cited by Harper (1956). The presence of genetically unselected material in the soil seed reserves is likely to slow down or reverse any tendency to selection for herbicide tolerance. However, if the species concerned is one with a relatively rapid seed turnover and the tillage system also favours more rapid cycling of the seed reserves then the development of resistance is more likely. In these respects modern husbandry may be said to favour the development of resistance. On the other side of the coin, a large and increasing range of herbicides is available so that, deliberately or by chance, there is in most crops an opportunity for rotation of herbicides. Such rotation of herbicide use should reduce the danger of selection for resistance.

This subject is to be dealt with more fully elsewhere in the conference. All that needs to be said here is that there is still room for discussion on the probability of herbicide resistance developing as a serious problem in our common weeds. However, if such a development does occur it could have a profound effect on our thinking in relation to herbicide use and systems of cultivation.

Possibilities for stabilisation of new systems

On some of our heavier soils one system has become relatively stable. That is the practice of growing winter wheat, following this by straw bruning, shallow tine cultivation, or some form of direct drilling and early planting of another winter wheat crop and so on repeated indefinitely. We are wholly persuaded that this system favours many annual grasses, notably wild-oats and blackgrass. Further the autumn germinating fraction of A. fatua populations appears to be favoured more than total seedling number. However, for many farmers, a return to mouldboard ploughing would be totally impracticable. If the cultural change is irreversible then we must devote ourselves to perfecting herbicide techniques to copy with the new situation. The problem is to apply a herbicide early enough to prevent competition from early germinating weeds without detracting from control of those germinating later. A. fatua plants emerging in March or April in a winter wheat crop are at a severe competitive disadvantage and produce much less seed than autumn germinators. However they may nonetheless produce significant amounts of seed if uncontrolled. Many farmers are responding to this problem by double spraying, or even treble or quadruple spraying their crops. We at WRO feel there is considerable scope for rationalising this process. There is a need to examine a greater range of product mixtures. It may also be that the application requirements for compounds applied in sequence are different to the requirements for single treatments. It is heartening to see that some of the herbicide manufacturers are aware of this problem; a new tank mix of metoxuron and barban and an agreed recommendation for sequential use of tri-allate and methabenzthiazuron are being recommended this autumn. One hopes other combined recommendations will follow this initiative.

Some problems of application remain. It is notoriously difficult to drive tractors on the land used for this system of farming during the winter months. Early post-emergence or even pre-emergence spraying can be extremely difficult or impossible. It is this difficulty which has stimulated much of our interest in techniques of low volume application; the subject of a separate session.

Another system is gradually evolving in which winter oil seed rape is grown. The rape is direct drilled very early in the autumn and this conditions cropping in several ways. First the rape crop is ideally preceded by winter barley or an early maturing spring barley variety. The rape, therefore, is sown with a built in problem of volunteer barley. Following the rape the general requirement is to get the land into winter wheat, rape being a very good entry for winter wheat. Here, too, a relatively consistent range of problems and possibilities is evolving. The problems are volunteer rape, slugs in the straw which may damage the crop, the physical problems left by the rape straw, and possible injury to the wheat crop from herbicide residues. This last problem has been discussed earlier and need not be taken further. Remarkably most of the weed problems of this completely new cropping sequence have been solved almost as soon as they became apparent. With the advant of herbicides for the mayweeds and cleavers as well as the grasses the weed control armoury is complete.

In summary, changes in husbandry practices can influence weeds and weed control to a marked extent. In only limited cases is it possible to modify cultural procedures to assist weed control. In rather more cases the Agrochemical Industry has to develop to meet the needs of a continually evolving Agriculture.

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Proceedings 1976 British Crop Protection Conference - Weeds

THE INFLUENCE OF CHANGING HUSBANDRY ON WEEDS AND WEED CONTROL IN HORTICULTURE

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Horticulture embraces a large number of individual crops which vary greatly in size, form and duration. The vegetables, of which more than thirty are grown in Britain, are mainly annuals; fruit crops are perennials, ranging from the herbaceous strawberry to top fruit; the ornamentals include bulbs, roses and the whole range of herbaceous and woody nursery stock. In each of these sectors the crop production methods are changing all the time, responding to economic and other pressures and incorporating advances in technology. Traditionally, horticulture has been labour-intensive and in the past 20 years or so it has been the rising cost of labour which has provided the greatest pressure. Two factors have been of major importance in enabling growers to meet this; one is the advance in mechanisation, the other is the development of selective chemical methods of weed control. These have proceeded in parallel and together have allowed profitability to be maintained. They have also brought about some changes in the way the crops are grown, which have in turn influenced the nature of weed problems. In this paper we shall attempt to outline the effects of these changes as they relate to outdoor horticultural crops and to comment on present and future requirements for weed control.

CHANGES IN CROP PRODUCTION METHODS

A major change that has occurred is the expansion of vegetable production in traditionally arable farming areas. There are various reasons for this, but it has been particularly associated with the rise of the processing industry and has involved those crops which can be grown in a mechanised system using minimal labour. Because the machines themselves are costly, they must be used to best advantage and this tends to limit the range of crops grown on any one farm. The areas of land especially suitable for growing certain crops are decreasing, and this also tends to promote specialisation among intensive growers.

A second general tendency that has occurred in vegetable production is towards increasing precision, associated with processing demands and the requirements of market outlets for phased supplies of standardised produce. In some crops this has led to higher plant populations and to patterns of plant arrangement which are especially suited to give maximum yields of produce with the desired size and quality characteristics. Concurrently with this there have been improvements not only in drilling and harvesting equipment but also in varieties, fertilizer usage, irrigation and pest and disease control.

The major change in the top fruit sector has been the adoption of hedgerow systems for apples, with advantages in terms of earlier cropping, better light interception, and ease of picking, pruning and spraying. The lower branches of such trees are so close to the ground that it is impossible to mow or cultivate between them after June when they are weighed down with fruit (Banwell, 1972). With strawberries, a substantial proportion of the crop is now protected by low polyethylene tunnels in order to hasten ripening; once the supporting wires are in position mechanical weeding is no longer possible, while hand weeding is too expensive.

In ornamental crops, most changes have been associated with increased mechanisation and a declining labour force. There has also been a major development associated with the advent of the garden centre, that of year-round marketing of container-grown trees and shrubs. These are grown in beds at spacings too close to permit easy access; the cost of hand weeding in such circumstances has been estimated as £3,600/ha, as against £360/ha for herbicide application by knapsack sprayer and £134/ha for tractor spraying (A.W.Hales and N.J.Hurford, personal communication).

There is no doubt that the discovery and rapid adoption of selective herbicides has been an essential factor in enabling the benefits to be realised from all the other improvements that have taken place. Initially regarded as a partial substitute for hand labour, herbicides are now relied upon to a large extent to prevent weeds from interfering in any way with crop production. This increase in herbicide usage, and the consequent reduction in the need for mechanical or manual hoeing, itself represents a significant change in husbandy.

CHANGES IN WEED FLORAS

Intensive vegetable cultivation, as practised in market gardens, involved high fertility, a close rotation of often short-term crops sown or planted at different times of the year and frequent soil disturbance by hoeing. These conditions tend to favour certain weed species rather than others and to result in a characteristic weed flora. It would include, for example, Stellaria media and Poa annua as almost invariable major components, whereas Sinapis arvensis, Papaver rhoeas and a number of other common weeds of farm land would usually be absent. Climatic and soil differences account for some regional variation (e.g. Solanum nigrum especially in the south and east, Polygonum persicaria especially in the north and west), but a general similarity is apparent in the weed floras wherever vegetables have been regularly grown for some time. An enquiry among horticultural advisers in 1953 and a survey of the viable seeds present in vegetable fields around 1960 gave similar results in terms of the species most commonly found (Table 1).

Data obtained in Norway during 1947-73 showed that the nine commonest weeds of vegetable crops, in decreasing order of frequency, were Chenopodium album, Stellaria media, Capsella bursa-pastoris, Senecio vulgaris, Matricaria matricarioides, Spergula arvensis, Poa annua, Polygonum spp. and Galeopsis spp. (Fiveland, 1975). Compared with the lists for England (Table 1), the main differences are the absence of Urtica urens and Veronica persica and the relative importance of Spergula arvensis and Galeopsis spp. This is in accord with the conclusion of Scragg (1974) that S. arvensis and Galeopsis spp. are more important and Veronica spp. less important as weeds of arable crops in Scandinavia and Scotland than they are in England.

It seems probable that the frequency of soil disturbance is a major factor which determines the weed flora of vegetable crops, discouraging perennials and those annuals with a long life-cycle. In a 9-year experiment, a rotation of vegetable crops in which no herbicides were used was substituted for one which had been based primarily on cereals. Determinations of the viable seeds present in the soil showed a progressive change towards the kind of flora found on vegetable holdings, with increases in the relative importance of Poa annua, Stellaria media and Senecio vulgaris while Aphanes arvensis, Papaver spp. and Veronica arvensis declined (Roberts & Stokes, 1965). The type and level of fertilisation may also affect the weed flora; Stellaria media and Veronica persica, for example are encouraged by continued application of farmyard manure (Mann, 1939; Roberts & Stokes, 1965). In a 50-year experiment with vegetable crops in Poland, Urtica urens and Chenopodium album were most abundant on plots which were organically manured but the differences in weed floras were quantitative and the species present were the same regardless of fertilizer treatment (Dobrzanski & Fajkowska, 1974).

Table 1

Annual weeds of vegetable crops in descending order of frequency

1953*	1959-63+	1970-75±
Stellaria media	Stellaria media	Poa annua
Urtica urens)	Poa annua	Matricaria spp.
Chenopodium album)	Urtica urens	Stellaria media
Poa annua	Senecio vulgaris	Polygonum aviculare
Senecio vulgaris	Capsella bursa-pastoris	Chenopodium album
Polygonum persicaria	Chenopodium album	Urtica urens
Capsella bursa-pastoris	Matricaria spp.	Capsella bursa-pastoris
Veronica spp.	Veronica persica	Veronica persica
Matricaria spp.	Polygonum aviculare	Viola arvensis

* Questionnaire survey (Roberts, 1954).
\+ Viable seeds in soils, 58 fields (Roberts & Stokes, 1966)
± Viable seeds in soils, 83 fields (H.A.Roberts and P.M.Lockett, unpublished).

There have undoubtedly been changes in the weed problems encountered in vegetable crops during the past 20 years. Unfortunately, they have not been documented in any quantitative manner, even to the extent that they have been in cereals (Fryer & Chancellor, 1970; Scragg, 1974). It is therefore difficult to assess the factors involved except in very broad terms. One change has certainly been associated with the merging of vegetables and farm crops. Where vegetables have been taken into a cereal rotation, changes which had previously occurred during cereal cropping are reflected in the vegetable phase. The spectrum of annual dicot weeds is likely to be more varied and problems with Avena fatua can arise, something which never happened in traditional vegetable culture. Specialisation in cropping and the reduced frequency of soil disturbance are probably factors which have led to increased concern about perennial weeds such as Agropyron repens and Cirsium arvense in annual vegetable crops; other factors such as less mouldboard ploughing and a succession of mild winters may also have contributed.

The other main identifiable reason for changes in weed problems has been herbicide usage itself. No herbicide kills all weed species at rates selective in a crop. If the surviving species mature and augment the seed bank in the soil, repeated use of the same herbicide can lead to a rapid change in the dominant species. A noteworthy example of this was the increase in Matricaria matricarioides on intensive vegetable holdings following introduction of formulations based on chlorpropham in 1958; the spread of Galinsoga parviflora was also assisted in this way.

Nevertheless, the annual weed flora of vegetable crops does not appear to have changed very markedly. Determinations of viable seeds in a series of fields from 1970 to 1975 showed that the species most frequently encountered were much the same as they were 10-15 years earlier (Table 1). The greater frequency of Matricaria spp. (including M.matricarioides, M.recutita and Tripleurospermum maritimum spp.inodorum), however, probably reflects a real increase in prevalence, and this is perhaps also true of Polygonum aviculare. The results showed that there were differences related to crop specialisation; Senecio vulgaris, for example, was more frequent where lettuce was regularly grown than in carrot-growing areas. Matricaria matricarioides is one of the species which has increased in arable crops as a whole in Norway over the past 25 years, whereas certain other species have declined (Fiveland, 1975). These changes are attributed to the tendency towards monoculture or the growing of just a few crops, together with greater mechanisation and extensive herbicide usage.

Fruit crops were traditionally maintained under clean cultivation or were grassed down. The main factor which has influenced the weed flora has undoubtedly been the widespread adoption of simazine and paraquat for maintaining control without cultivation. This led to problems with perennial weeds and with those annuals such as Polygonum aviculare which are relatively tolerant to these herbicides (Roach, 1966). Weed population shifts arising from continued use of a single herbicide in a long-term crop have been reported from many parts of the world (e.g. Skroch, Sheets & Monaco, 1975). Problems of this kind, caused by species already present, can be anticipated. The weed-free environment, however, provides ideal conditions for establishment of external species from chance propagules if they should happen to be sufficiently tolerant to the herbicide; hedgerow species such as Heracleum sphondylium may develop into unexpected problems (Banwell, 1972).

Many perennial crops, among them asparagus, blackcurrants and raspberries, produce viable seeds which can establish under non-cultivation because they tolerate the basic herbicide treatments, and after several years crop seeds may be a major component of the viable seed population of the soil (Clay and Davison, 1976). So far, however, this has not proved serious. In annual vegetable crops, on the other hand, volunteers from previous crops can often be troublesome; they frequently tolerate the normal herbicides employed, and benefit just as the crop does from reduced competition. Wherever potatoes are included in the rotation, volunteers can be found in succeeding crops, while cereals may occur especially in such crops as spring cabbage.

PRESENT STATUS OF WEED CONTROL

Vegetable growers have come to rely heavily on herbicides. Virtually the entire acreage of peas, beans, onions, carrots, red beet and many other crops receives one or more herbicide treatments, but in transplanted brassicas mechanical cultivation can provide adequate control and herbicide usage is at a low level. For most crops a range of herbicides is available and many particular problems, such as Matricaria spp. in carrots and Polygonum aviculare in onions, have been alleviated by the introduction of chemicals with appropriate activity. There still remain, however, some situations in which there is no satisfactory answer, like the problem of Compositae in lettuce.

A high standard of weed control is needed. Not only are some of the crops ill-equipped to compete with weeds, but it is essential that weeds do not interfere with harvesting and freedom from particular species, such as Solanum nigrum in peas, may be vital. Under good conditions, the existing range of herbicides can give the results required; the difficulties arise when conditions are less favourable so that performance is less good. The surface-applied pre-emergence treatments, which are frequently employed in vegetable crops, are especially prone to variation in performance because of their dependence on soil moisture. If they fail and there is no satisfactory follow-up treatment there may be considerable or even complete crop loss.

The two requirements of reliability and control of an extended range of weeds are being met to an increasing degree by the use of herbicides in combination as mixtures, either formulated or tank-mixed, and as sequences or programmes. A significant development in the past few years has been acceptance of this concept by the agrochemicals industry, which has led to joint recommendations by companies for their respective products. This is realistic and of great value to the grower.

Herbicide usage is now a corner stone of modern orchard management (Banwell, 1972) and there is widespread use in bush, cane and soft fruit. The available herbicides cope with most weed situations but many widely used treatments, especially on young crops, are not based on label recommendations. Simazine, for example is widely used after planting bush, cane and top fruit, whereas most labels stipulate that they must have been planted for one season. In top fruit, growth-regulator herbicides are widely used as directed sprays but even where there are recommendations these often derive from practice; this has been the tradition for many years (Roach, 1966). Variation in performance of soil-acting herbicides is still a problem, particularly in newly planted crops. Once established, there is greater opportunity to select favourable conditions and more use is being made of autumn and late winter applications to avoid dry soil conditions likely in spring. The need to prevent build-up of resistant weeds, particularly perennials, has long been accepted, even though some spot treatments may damage the crop (Roach, 1966; Walker, 1973).

The standard of weed control achieved in ornamental crops varies widely according to growers' attitudes towards herbicides. In the production of bulbs and roses, either as part of an intensive arable rotation or in a specialist nursery, high standards of weed control are usual. It is also true of the large hardy plant nurseries; this is a tribute to the growers, who have developed successful treatments following indications from official tests. On some smaller nurseries, especially in the traditional areas, few herbicides are used, largely because of fears of crop damage.

FUTURE REQUIREMENTS

Innovations in crop production have had the primary aim of increasing yields, facilitating harvesting, reducing labour requirements, simplifying management and generally improving efficiency. Although on occasion herbicides have brought about a direct change, for example to a bed system for low-growing nursery stock to permit tractor spraying (Humphrey, 1972), their role has generally been a supporting one in allowing the other improvements to be introduced. We see this role continuing, with the need for a range of materials and techniques sufficiently wide to give flexibility to meet future demands.

These can arise if a new crop is introduced, as has happened in agriculture with oil-seed rape, or if an existing crop is grown in a different context. The overwintered bulb onion crop provides an example of this. By drilling suitable cultivars in late summer, high yields of bulbs can be obtained during May - July, well before the spring-sown crop matures (Tucker & Hough, 1973). The weed flora developing on seedbeds prepared in August differs from that in March; Poa annua and Stellaria media are relatively more important while Polygonum aviculare, a major weed of spring-sown crops, does not usually occur since August is outside the normal germination period. Whereas the spring-sown crop is characterised by very slow initial growth and rapid later development, the reverse is true for the overwintered crop. This has a bearing on the use of post-emergence herbicides with contact action; injury is likely to be greater because of poor wax development and its effects more severe because of subsequent frost damage or fungal infection. These factors are common to the overwintered salad onion crop, although the bulb crop is of longer duration and there is a greater need to suppress spring-germinating weeds. The main difference, however, is the context in which the crop is grown. Salad onions are produced by specialist market growers in horticulture rotations; the overwintered bulb crop has been largely taken up by farmers with the necessary mechanisation, and is grown with low labour input. This involves reliance on effective chemical weed control and the deployment of the existing herbicides for onions to achieve it in this new situation. One specific problem that has arisen is the presence of volunteer cereals; these have not caused difficulty in the spring-sown or salad crops, and this particular problem remains to be solved satisfactorily.

Another requirement is to avoid replacing an existing weed problem by another, possibly more intractable. The ability of weed species to persist as viable seeds in the soil means that if circumstances should change, there is a potential for increase in any one of those represented. Roberts & Stokes (1965) showed that when vegetables succeeded a cereal rotation the numbers of seeds of species associated with cereal cropping progressively declined, yet after 9 years almost all were still represented in the seed population. Fryer & Chancellor (1970) also concluded that although continued herbicide usage in cereals had reduced weed densities, there had been little effect on diversity. It is not surprising therefore that if germination can occur at a time which allows maturity to be reached before harvest, and there is tolerance to the herbicide used, even a minor component of the weed flora may rise to prominance, aided by lack of competition from those species which are killed.

The possibility that resistance to herbicides might develop in weed species is also a real one; Chenopodium album has now been added to the short list of weeds in which triazine-resistant populations have been found (Bandeen & McLaren, 1976). With the trend towards specialisation in cropping likely to continue, the need for a sufficient range of treatments to permit rotation of herbicides (Abel, 1954) will become more acute. The management aspect is also important here; special attention in preceding crops to species likely to cause particular difficulty is often justified (Lawson, 1972). This applies notably to perennial weeds such as Agropyron repens. These may be kept at tolerable levels if advantage is taken of the increasing knowledge of their biology to ensure that so far as possible the practices employed act against them and do not encourage multiplication and spread.

If a herbicide programme leaves only a few plants of a particular tolerant species, there may be a case for removing them by hand in order to prevent build-up. This is analogous to the roguing situation with Avena fatua, where there is ample evidence to justify rigorous attempts to prevent return of seeds to the soil (Wilson & Cussans, 1975). In some situations, the high crop values and seed costs make the use of soil sterilants such as dazomet economic; this can be true of ornamental nurseries and Brussels sprout plant-raising beds. Weed control is only one of the benefits of such treatments, and some increase in their use in such crops as lettuce seems probable. In fruit crops it is possible that non-competing species could be used to suppress those weeds which are most difficult to eradicate with herbicides. An integrated system of this kind has been described for suppression of Convolvulus arvensis and Calystegia sepium in vines by using either sown species or selected weeds which do not compete with the crop (Stalder, Potter & Barben, 1973a). The possibility of allowing the natural flora of orchards to remain for certain periods and the use of alternative ground covers, such as clover, is being actively investigated (Stalder, Potter & Barben, 1973b; Stott et al, 1976). In Holland, experiments are in progress with Sedum acre which seems to be well suited for use under apples. It can be established from seed or plantlets, tolerates simazine and aminotriazole, but can be killed when required by diuron or bromacil (D.van Staalduine, personal communication).

In horticulture as a whole, labour costs are a major consideration. For individual growers profitability will continue to be more important than maximising yields and greater mechanisation can be anticipated, perhaps requiring changes in cropping methods. Already in blackcurrants the bed system has given way to wide rows to permit mechanical picking. In apples also, there is interest in mechanised harvesting, and this plus the cost of trees is likely to determine whether orchards follow the super-intensive plan envisaged at Long Ashton Research Station or a hedgerow system. Whatever techniques are adopted in fruit or in other horticultural crops, there will be a requirement for reliable and effective control of weeds.

The prime limiting factor in selective weed control is crop tolerance; different crops tolerate different herbicides. The problem in horticulture is the range of crops and the comparatively small areas they occupy, so that their market potential for chemicals is low and because of the crop values, the risks are high. Reverting to the example cited earlier of container-grown nursery stock, the herbicide cost was £96/ha, yet the crop could be worth £50,000/ha. Some aspects of herbicide development for minor crops were considered at the previous Conference (Whitwell,1974).

The basis for herbicide usage in the United Kingdom is label recommendation, endorsed by the Agricultural Chemicals Approval Scheme. These recommendations now cover vegetable crops fairly adequately, providing growers with the means to obtain effective weed control in most circumstances. Certainly, if herbicides better in spectrum of activity and reliability were to appear, they would be welcomed. There is, in a number of crops, a dearth of post-emergence treatments with the necessary activity to back up the initial pre-drilling or pre-emergence applications and to cover for the variability which is bound to occur. In general, however, existing herbicides, used in programmes with proper appreciation of the weed problem and the capability of the chemicals, and with overall good management, provide satisfactory results.

In fruit and ornamental crops, the position is less satisfactory. Banwell (1972) pointed out that fruit growers do not need new herbicides so much as more information on just what those available will do. We would endorse this, and suggest that it might be possible to provide data sheets with detailed information on crop and weed response presented in such a way that a grower could decide on how to deal with an unfamiliar weed problem. The vast majority of growers recognise the difficulty which the manufacturers have in providing and backing label recommendations for such a wide range of small-acreage crops, and are prepared to accept some risk of crop damage if the weed situation is serious or likely to become so. While recognising the difficulties that could arise in respect of clearance, we feel that there is merit in the data-sheet approach and envisage that information both from manufacturers and state-supported institutes would be combined. This kind of information would enable growers and advisers to make objective decisions on the suitability of various possible solutions to the varied and unusual weed problems that frequently arise in this area of horticulture. In this way the usefulness of the existing widely-used programmes can be maintained and the necessary high standard of weed control secured.

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THE INFLUENCE OF TILLAGE ON THE WEED FLORA OF FOUR SITES SOWN TO SUCCESSIVE CROPS OF SPRING BARLEY

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Summary Weed populations were recorded on four experiments designed to examine the effects of cultivation on crop growth. The treatments were mouldboard ploughing, shallow or deep tine cultivation and no cultivation except that caused by drilling and harrowing.

There were most seedlings of dicotyledonous species on plots receiving most cultivation. Some of the most numerous species e.g. Polygonum spp, Sinapis arvensis and Raphanus raphanistrum showed the greatest response to cultivation. Many of the less numerous dicotyledonous annuals were influenced very little or not consistently by cultivations.

The annual grasses, Avena fatua and Alopecurus myosuroides were favoured by reduced cultivation.

A number of perennial species were recorded; including Rumex spp., Taraxacum officinale, Convolvulus arvensis and Agropyron repens. Most were favoured by direct drilling.

Resumé Des populations d'adventices ont été determinées dans 4 expériences ayant pour but d'étudier l'influence des facons culturelles sure la croissance des cultures. Les facons etudiées étaient les suivantes: labourage avec charrue à soc 1, labourage plus 2 où moins 3 profond avec cultivateur à dents et aucune facon culturelle á sauf le passage a'un semoir et d'une herse 4. Les plantules dicotylédonées etaient les plus nombreuses dans les parcells recevant les traitements 1 et 2. Cette réponse n'etait pas constante; dans le cas de certaines espèces très nombreuses plus il y avait de labourage plus les populations augmentaient. Pour ce qui est des dicotylédones annuelles moins nombreuses, les facons culturelles ont eu peu d'influence. Les graminées annuelles, Avena fatua et Alopecurus myosuroides, ont béneficié de la non-culture. Plusieurs espèces vivaces ont été notées, y compris Rumex spp., Taraxacum officinale, Convolvulus arvensis et Agropyron repens. Cha plupart de celles-ci ont béneficié du semis direct.

INTRODUCTION

In 1967, the Weed Research Organization and the Letcombe Laboratory began a joint project to compare the effects of different degrees of tillage on soil conditions, on root and aerial growth and on the yield of cereals. The choice of chemical for weed control was the best available and it was applied to all the treatments. The weed flora was monitored to ascertain the response of weeds to the changing circumstances, and to provide information on the weeds for future weed control.

The joint tillage project began with experiments on both spring barley and winter wheat on three different soil types: sandy loam over gravel at Begbroke, silt loam over chalk at Compton and clay loam at Buckland. A pilot experiment with spring barley was first conducted on the sandy loam soil (Begbroke I). Elliott et al (1977) have described the main spring barley experiment at Begbroke. This paper considers the responses of weeds in this and in the main spring barley experiments on the three soil types.

METHOD AND MATERIALS

Autumn or winter ploughing (P) was compared with deep tined cultivation (DT), shallow tined cultivation (ST) and no tillage (NT). These involved inversion and disturbance to 22 cm on P and disturbance to 16 cm and 8 cm on DT & ST. Before drilling, seedbeds were prepared by traditional cultivation on P, DT & ST plots but NT plots were direct drilled. Apart from the ploughing and cultivations including seedbed preparation all other treatments were applied universally to all plots. Dates of all operations are given in Table 1.

All experiments were randomised blocks with only 2 replicates at Begbroke I but 3 replicates at Begbroke II and Compton and 4 replicates at Buckland. The 4 treatments were compared at all sites except Begbroke I where ploughing (P) was omitted. Plots were large (300 - 500 m^2), separated by wide discards (8 - 12 m^2) to allow for the use of machinery and a range of crop assessments. Herbicide usage (see Table 1) was mostly at recommended doses. However, aminotriazole was used at Begbroke II and Buckland at half recommended dose on a low population of Agropyron repens. A split application of the normal dose was made at Begbroke I in 1970.

Broad-leaved weeds and shoots of A. repens emerging in spring were counted in 20 - 40 (random) quadrats per plot of either 529 cm^2, or 900 cm^2, according to weed density.

Wild-oat plants and panicles were counted as they were rogued in July. Bindweed shoot numbers were recorded at the spring broad-leaved weed assessment and, also, in 100 x 900 cm^2 quadrats/plot at Buckland in September 1975.

RESULTS

A. Seedling annual weeds

Table 2 shows the occurrence and abundance of seedling weed species emerging in the growing crops. The figures refer to the cultivation treatment on which the particular weeds were most abundant. More than 39 species were recorded on the experiments and 19 of these occurred at densities in excess of 3.17 plants/m^2 on at least one treatment and season. The number of weed species and plants varied widely from year to year and site to site. The highest number of species recorded at a single assessment was 29 at Begbroke II in 1973. At the other extreme, the number of weeds present at Compton in 1971 and 1972 and at Buckland in 1974 and 1975 were too few to assess. The species varied in importance on each site. At Buckland, black-grass, Alopecurus myosuroides, was numerous in 1973, in the second spring barley crop after a long run of winter wheat. In subsequent years it declined to low levels. Stellaria media and species of Sonchus and Cirsium were also important but at levels of less than 10 plants/m^2. At Compton, Polygonum spp., Veronica persica, Stellaria media and Viola arvensis were abundant together with the unusual weed Sambucus nigra and in 1973, Trifolium repens. On Begbroke II, 6 species exceeded 3.17 plants/m^2 on some treatments at some time but consistently important amongst these were Polygonum aviculare, P. convolvulus, P. persicaria and the brassiceae, Raphanus raphanistrum and Sinapis arvensis. Poa annua was numerous in 1973. Begbroke I produced more weeds than the main sandy loam site and 11 species exceeded the 3.17 plants/m^2 level at some time.

Table 1

Dates of salient cultural operations and herbicide applications

	Begbroke I				Begbroke II					Compton					Buckland		
	67/8	68/9	69/70	70/1	68/9	69/70	70/1	71/2	72/3	69/70	70/1	71/2	72/3	72/3	73/4	74/5	75/6
Harvesting		21.8	27.8	11.8		27.8	11.8	9.8	7.8		25.8	18.8	23.8	26.8	15.8	22.8	14.8
Straw burning (removal)			5.9	26.8		(4.9)	27.8	6.9	6.9		end.8	7.9	30.8	6.9	30.8	10.9	21.8
Spraying																	
paraquat		1.10			4.11			1211		2210	15.9+ 24.9	1111	3.10	2.10			
aminotriazole (with ammonium thiocyanate)	2212		29.9	14.9+ 28.9		30.9	14.9		1710						8.10	1.11	
TCA		23.9						1211									
glyphosate																	22.9
Ploughing	n.a.	n.a.	n.a.	n.a.	2110	1411	5.11	8.2	3.11	1211	15.9	1611	1711	6.10	1.11	1510	6.11
Cultivating (ST & DT)	29.1+ 20.2	2310	1811	21.9	2210	1811	28.9	21.1-24.2	14.11	1211	25.9	2211	2311	1210	2.11	2210	30.9
Spraying paraquat				10.3				24.2			16.3		5.3	16.2+ 16.3	27.3	13.4	27.1
Preparing seedbeds	19.3	10.3	19.3	10.3	10.3	19.3	11.3	20.3	7.3	25.3	25.3	23.3	14.3	19.3	30.3	21.4	19.2
Drilling & harrowing	19.3	24.3	20.3	11.3	26.3	23.3	12.3	21.3	8.3	25.3	25.3	24.3	14.3	20.3	2.4	22.4	25.2
Spraying																	
Dichlorprop		20.5			20.5												
Ioxynil/mecoprop			13.5	29.4		13.5	29.4										
Dicamba/mecoprop/MCPA								17.5	11.5								
Dichlorprop/MCPA										27.5	12.5	19.5					
Dicamba/benazolin/MCPA													18.5				
2,4-D ester															25.5	4.6	
Spreading																	
tri-allate granules														22.3			

Table 2

The occurrence and abundance of seedling weed species

	Begbroke I			Begbroke II					Compton		Buckland
	68	69	70	69	70	71	72	73	70	73	73
Alopecurus myosuroides											4
Anagalis arvensis							3	2		1	1
Aphanes arvensis				1		1	1	1			
Avena fatua			1					1			
Capsella bursa-pastoris	3		2		1		1	1			1
Cerastium spp		2				1	1	1	1	1	1
Chenopodium album					2	1	1	1		1	1
Chrysanthemum segetum			2								
Cirsium spp							1	1	1	1	2
Epilobium spp								1			1
Euphorbia spp								1			
Fumaria officinalis	1	1	1	1			1	1	1		
Galium aparine						1		1		1	
Hypochaeris radicata								1		1	1
Lamium amplexicaule										1	1
Lapsana communis								1			
"Mayweeds"			3		1	1	1	2			1
Papaver rhoeas								1	1		1
Poa annua								3		2	
Polygonum aviculare	3	4	5	3	4	4	4	4	2	2	1
" convolvulus			2		3	2		2	3	2	1
" lapathifolium								2			
" persicaria		4	2	2	3	2		1		1	
Ranunculus spp				1		1	1	1			
Raphanus raphanistrum+ Sinapis arvensis	5	5	5	3	3	2	3	2			1
Rumex spp.			3				1				
Sambucus nigra							1	1	3	2	
Senecio vulgaris	3	3	4	1	2	1	2	1			1
Sisymbrium officinale							1				
Solanum nigrum							1				
Sonchus spp		3	3			1	2	2		1	3
Spergula arvensis		3	3		1		1				
Stellaria media		2	1	1	2	1	2	2	3	2	3
Taraxacum officinale		3					1	1			1
Trifolium repens							2	2	1	3	1
Urtica urens								1			
Veronica persica							1		3	2	1
Viola arvensis	4	4	5	1	2		1	1	2	1	
Total seedling weeds	5	6	6	4	5	4	5	4	4	4	5
Number species recorded	6	11	14	9	11	13	23	29	11	17	21

Population index on treatment having most of the species

1 = < 1 plant/m^2; 2 = 1.01 to 3.16; 3 = 3.17 to 10.0; 4 = 10.1 to 31.6; 5 = 31.7 to 100; 6 = > 100 plants/m^2.

The herbicides gave good control of all species on all treatments and there was little evidence of build up of any annual species during the course of these experiments. One possible exception was Aphanes arvensis. This species showed no response to cultivation in the seedling phase. However, it is moderately resistant to the herbicides used in spring and to paraquat. In the latter stages of the Begbroke II experiment there were many more large surviving plants of A. arvensis on the NT plots than on other treatments.

The effect of increasing tillage was to cause an increase in the total population of seedling weeds in all years on both Begbroke experiments (table 3). (Standard errors are not given for results of Begbroke I because replication was too small to provide good accuracy). This trend was also seen at Compton in 1973, although little effect was observed in 1970. At Buckland the opposite effect was observed in 1973, the only year in which a substantial population of seedling weeds emerged. NT plots carried more than 8 times as many weeds as P plots.

Table 3

Total dicotyledonous seedlings plants/m^2
(logarithmically transformed data in parenthesis)

	Year	NT	ST	DT	P	SE
Begbroke I	1968	12.1	48.1	62.7	-	-
	69	19.6	107.5	204.6	-	-
	70	31.0	139.7	215.5	-	-
Begbroke II	69	2.9 (0.596)	4.7 (1.366)	6.9 (1.820)	18.3 (2.772)	(0.504)
	70	9.6 (2.240)	28.3 (3.309)	37.2 (3.576)	35.5 (3.389)	(0.256)
	71	7.9 (1.965)	11.5 (2.415)	16.0 (2.437)	28.0 (3.270)	(0.403)
	72	8.1	9.3	19.1	32.8	7.3
	73	6.5 (0.871)	26.1 (1.408)	17.8 (1.257)	23.2 (1.342)	(0.053)
Compton	70	21.7	22.2	25.2	24.0	4.5
	73	7.0	8.3	16.5	17.1	3.2
Buckland	73	15.3 (0.863)	5.4 (0.672)	2.2 (0.446)	1.8 (0.423)	(0.223)

The response of individual weed species to cultivation varied. Five groups were identified.

1. Species that were increased by tillage

This group included most Polygonum species (table 4), especially P. aviculare, and Raphanus raphanistrum together with Sinapis arvensis (table 5). Capsella bursa-pastoris and possibly a few other species also showed this trend but numbers were too small to be reliable. P. aviculare showed the response very consistently at Begbroke but less so at Compton although total Polygonum species increased with tillage. R. raphanistrum with S. arvensis were found mostly at Begbroke where they consistently responded to increased tillage.

Table 4

Total Polygonum spp plants/m^2
(logarithmically transformed data in parenthesis)

	Year	NT	ST	DT	P	SE
Begbroke I	1968	0.22	3.58	4.26	-	-
	69	3.42	26.87	23.51	-	-
	70	16.84	76.92	58.55	-	-
Begbroke II	69	0.46 (0.351)	1.62 (0.909)	2.78 (1.303)	10.65 (2.322)	(0.264)
	70	3.62 (1.207)	19.99 (2.929)	32.11 (3.450)	24.88 (2.956)	(0.290)
	71	4.94 (1.383)	8.40 (1.958)	12.22 (2.176)	21.73 (3.017)	(0.520)
	72	0.61 (0.184)	5.38 (0.765)	9.22 (0.909)	22.96 (1.299)	(0.175)
	73	0.72 (0.212)	12.06 (1.104)	7.74 (0.927)	14.40 (1.454)	(0.095)
Compton	70	2.80	3.32	6.39	7.92	2.73
	73	1.07	0.89	3.49	3.95	0.90
Buckland	73	0.28	0.28	0.15	0	n.a.

Table 5

Raphanus raphanistrum + Sinapis arvensis plants /m^2
(logarithmically transformed data in parenthesis)

	Year	NT	ST	DT	P	SE
Begbroke I	1968	0.47	2.02	5.82	-	-
	69	0.67	35.61	136.72	-	-
	70	0	9.57	61.24	-	-
Begbroke II	69	1.27	1.16	3.24	4.40	1.43
	70	0 (0)	0.43 (0.329)	1.28 (0.642)	3.19 (1.215)	(0.263)
	71	0.37 (0.249)	0.12 (0.105)	1.48 (0.565)	2.35 (1.187)	(0.307
	72	0.36	0.11	1.54	3.48	0.56
	73	0.18	0.18	0.72	1.26	
Buckland	73	0	0	0.09	0.19	n.a.

2. Species reduced by mouldboard ploughing

Sambucus nigra was found to reach high population levels at Compton in 1970, when treatment differences reached a high level of statistical significance (table 6). The population increased with decreasing tillage to a maximum on NT. In 1973, however, NT and P were similar with small numbers whilst tined cultivation produced significantly more plants than either of these treatments. The species was not observed at Buckland but small numbers were recorded at Begbroke in later years.

Table 6

Sambucus nigra plants/m^2
(logarithmically transformed data in parenthesis)

	Year	NT	ST	DT	P	SE
Begbroke II	72	0	0.33	0.33	0	0.33
	73	0.37	0.56	0.37	0	0.40
Compton	70	8.40 (5.096)	6.39 (4.956)	3.59 (4.406)	0.26 (0.936)	(0.447)
	73	0.27	2.07	1.69	0.35	0.30

Table 7 gives the numbers of Avena fatua removed at Begbroke I when plots were rogued on 22 June 1970. Many more plants were found on NT plots. Wild oats were very few in number at Begbroke II and absent from Compton but Buckland had very high populations. The Buckland experiment was treated with tri-allate granules in 1972 and 1973 and hand rogued in 1973 and each year thereafter. The number of plants was significantly lower after ploughing than after tined cultivation or direct drilling. In 1974, direct drilled plots had significantly more panicles than tine cultivated.

Mayweeds, mainly Matricaria matricarioides were least numerous on ploughed plots. Response to cultivation varied but these species were always most numerous on either direct drilled or tine cultivated plots.

Table 7

Avena fatua and Alopecurus myosuroides

	Year	NT	ST	DT	P	SE
Avena fatua						
Begbroke I panicles per plot at roguing	70	44.5	1.5	1.0	-	-
Begbroke II plants/m^2	73	0.002	0	0.022	0.004	0.009
Buckland panicles/m^2	73	0.35 0.66	0.18 0.34	0.29 0.28	0.06 0.08	0.12 0.10
plants/m^2 at roguing	75	0.22	0.32	0.31	0.05	0.06
Alopecurus myosuroides						
Buckland plants/m^2	73	10.94	30.91	30.85	7.28	2.91

3. Species increased by tined cultivation

Blackgrass, *Alopecurus myosuroides*, (table 7) was recorded only in 1973 at Buckland in which year it was particularly favoured by tined cultivation.

4. Species showing an inconsistent response

Stellaria media was favoured by no cultivation on Begbroke II in 1970 and at Buckland in 1973. In contrast, it was favoured by increased tillage at Compton both in 1970 and 1973, indicating that the response was not due to climatic factors. Other weeds behaved in similar fashion. These included *Poa annua* and *Senecio vulgaris*. Frequently the numbers present were too small to indicate a trend reliably.

5. Species showing no response

This was the largest group. It included *Anagallis arvensis*, *Aphanes arvensis*, *Chenopodium album*, *Chrysanthemum segetum*, *Euphorbia* spp., *Fumaria officinalis*, *Galium aparine*, *Lamium amplexicaule*, *Lapsana communis*, *Papaver rhoeas*, *Sisymbrium officinale*, *Solanum nigrum*, *Urtica urens* and *Veronica persica*. But many of these were present in such low numbers that no response could be reliably observed.

B. Perennial Weeds

1. Species arising from seed

Seedlings of some perennial species were recorded, notably, *Trifolium repens* and *Taraxacum officinale*. Numbers were small and the seedlings were usually killed or suppressed by the herbicide used. However, it was noticeable that there was a slow annual increase of mature plants of these species on direct drilled plots. These species also increased on the tine cultivated plots but to a lesser extent. A few plants of cowslip, *Primula veris*, were found each year on the direct drilled plots at Compton. They appeared to have germinated in autumn and survived the spring application of paraquat but they succumbed to the herbicide used against broadleaved weeds.

2. Species originally present as mature plants

The most difficult weed to control was couch-grass, *Agropyron repens*, (table 8). The Begbroke I experiment was started on a site having an initially large population of this weed. A combination of 6.72 kg/ha aminotriazole and tine cultivation considerably reduced couch population in 1970. On NT plots, the chemical alone suppressed the weed but was less effective. On Begbroke II the *A. repens* population was low at 0.55 shoots/m^2 on 22.4.69. A build-up was prevented by routine applications of 3.36 kg/ha aminotriazole sprayed each autumn. At Compton, where paraquat alone was used, small patches became established on areas of NT plots where bare soil had been exposed by sampling. A high population of *A. repens* at Buckland was treated with TCA and cultivations in the year before the experiment was started and the population remained at a low level until 1975 (table 8) when it began to multiply on NT plots. The barley crop was drilled late and suffered from drought allowing the weed to develop. An autumn application of glyphosate was made. A feature of the growth of couch on NT plots on all sites was its concentration into finite areas of high density. Spread from these areas took place only slowly.

Table 8

Agropyron repens shoots/m^2
(logarithmically transformed data in parenthesis)

		NT	ST	DT	P	SE
Begbroke I	3 May 68	263.8	132.3	102.3	-	-
	29 Apr 69	70.2	116.9	62.5	-	-
	7 May 70	183.2	17.7	4.8	-	-
Begbroke II	29 Apr 69	0.81	0.69	0.1	0.58	0.98
Buckland	75	12.62 (2.837)	2.31 (0.751)	0.17 (0.484)	0.17 (0.455)	(0.484)

Convolvulus arvensis was observed only at Buckland. It emerged late in spring and made little foliar growth after harvest, thus resisting efforts to kill it with herbicides. It did not occur over the whole site but remained in definite patches throughout the experiment.

Polygonum amphibium was not specifically assessed but was present at Begbroke. As with C. arvensis, it did not show any response to cultivation treatment but remained in the same location throughout the experiment. Cirsium arvense was present at Begbroke and Buckland and showed a slow increase over the years on direct drilled plots. However, plant numbers were few and they did not become important.

DISCUSSION

Major effects of cultivation on the weed flora were recorded. Table 3 shows that increased levels of cultivation led to greater numbers of broadleaved weed seedlings. This confirms earlier observations (Cussans 1966, Bachthaler 1974). Some of the most numerous species such as P. aviculare, S. arvensis and R. raphanistrum were particularly favoured by cultivation.

Herbicides were applied over all treatments, regardless of weed density, and excellent weed control was achieved. We decided to spray regardless of economics but we felt that most practical farmers would also have been reluctant to withhold a routine spray for broadleaved weed control from direct drilled plots, even though weed levels were relatively low. The reduced weed emergence on direct drilled plots should therefore be regarded as mainly of long-term and ecological interest. In fact there were no continuous long-term trends caused by tillage in populations of broadleaved weeds. The ratios between seedling numbers on ploughed plots and numbers on direct drilled plots remained relatively steady throughout the experiments. There was no tendency for the differences to increase with time as might be expected. It must be presumed that long-term trends of this type are diluted by the presence of large reserves of dormant seeds in the soil.

The most unexpected result was the occurrence of Sambucus nigra. This species is not common as an arable weed but occurred at high densities on the Compton experiment (table 6). In 1970 this species was favoured by direct drilling but, in 1973 seedlings were most numerous on tine cultivated plots. These differences are not easy to explain. It may be, in experiments of this kind, that effects beyond our control may occur. Some plots could be more attractive to berry eating birds e.g. Fieldfares or Starlings.

Previous work with Avena fatua has shown a high mortality of freshly shed seed exposed on uncultivated stubble surfaces, (Wilson & Cussans 1972, 1975, Wilson 1972). This work indicated that direct drilling of spring barley would result in reduced A. fatua populations compared with mouldboard ploughing. Conversely tine cultivation led to increased infestations, compared with mouldboard ploughed plots. The results reported here confirm the latter finding; there were more plants on tine cultivated plots than on those mouldboard ploughed. However, the direct drilled plots, in contrast to earlier results, had consistently more plants than ploughed plots, sometimes by a very wide margin (table 7).

The mortality of freshly shed seed can have played little part in these experiments which were treated, chemically and/or by hand roguing to reduce seed production to an absolute minimum. It seems possible in these experiments that some of the earliest emerging seedlings of A. fatua survived on the direct drilled plots, whereas they were killed by seedbed cultivation on the tilled plots. This fraction of the population would have emerged just too late to be killed by pre-drilling applications of paraquat but in advance of the crop.

Alopecurus myosuroides which is discouraged by spring cropping was of less significance in these experiments and only occurred at Buckland. It declined less rapidly with tine cultivation. Experiences elsewhere (Cussans 1975) suggest that A. myosuroides and Avena species are major problems or potential problems in winter sown crops established by reduced cultivation techniques.

Perennial weeds, where they occurred uniformly enough to be recorded reliably, were favoured by direct drilling. This is well known in respect of A. repens and not surprising. Some species characteristic of grassland were favoured in this way, notably Rumex spp., Taraxacum officinale and Trifolium repens. These latter species were not important agriculturally but provided an interesting example of the weed flora adapting to changed cultural practice.

Acknowledgements

We would like to thank many colleagues, past and present, who have helped with weed assessment; most notably P.D. Smith, P. Ayres, J. Carrington and C. Ellis.

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SEQUENTIAL USES OF HERBICIDES

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Summary Sequential treatments of crops with pesticides is common practice in many intensive growing areas. Such treatments are expanding into predominantly cereal areas with new techniques of autumn applied herbicides. Demands by processors, housewives, and caterers, for food, free of contamination of weed, pest and disease put constant pressure on the growers standards. Shortage of skilled farm labour and sophisticated machinery also dictate the necessity for weed free crops. There are many unknown factors relating to synergistic effects of one herbicide on another. Also residues left in the soil from previous crop treatments, which may be harmless on their own, can have disastrous effects when a further residual chemical is applied to a succeeding crop. A grower may use sequential treatments of herbicides on a crop from two to three manufacturers. Who is to tell him this is safe? Who is responsible should complaints arise for crop damage? Are manufacturers helping their distributor enough with advice in such situations? Do government backed units do enough in this field?

Sommaire Les traitements successifs des recoltes avec des pesticides est pratique courante dans de nombreuses regions agricoles a culture intensive. De tels traitements sont en voie de developpement sur des surfaces ou les cereales predominent, avec de nouvelles techniques utilisees en automne en ce qui concerne l'application d'herbicides. Les demandes faites par les industries alimentaires, les consommateurs, les hotelleries, en nourriture exempte de contamination dues aux mauvaises herbes, aux animaux nuisibles et aux maladies portent une pression constante sur la qualite offerte par les producteurs. Le manque d'ouvriers agricols qualifies, de machines sophistiquees impose la necessite de produire des recoltes saines. De nombreux facteurs se rapportant aux effets synergitiques d'un herbicide sur un autre restent inconnus. Aussi, des residus laisses dans le sol, et provenant de traitements effectues sur des recoltes anterieures, qui etaient par eux-memes sans consequence peuvent avois des effets desastreux lors qu'un second produit chimique avec residus est applique a une recolte succedante. Un producteur peut utiliser, a la suite, divers traitements d'herbicides manufactures par differentes firmes sur une meme recolte. A qui est-ce de lui dire que cette practique est sans danger? A quels responsables doivent etre portees les plaintes en cos de dommages des recoltes? Est-ce que les fabriquants de produits chimiques aident suffisamment par leurs conseils les detaillants dans de telles situations? Est-ce que les organisations qui ont l'appui du gouvernement font enfin assez dans ce domaine?

INTRODUCTION

In intensive growing areas such as South Lincolnshire and the Isle of Ely the necessity for long term thinking in weed control has always been a feature of the farming scene.

Whereas in many other areas of Britain onions, carrots, parsnips, green beans and vining peas are looked upon as horticultural crops, the vast acreages grown by fen and marsh farmers put such crops in similar categories that sugar-beet and barley would rate in say Yorkshire or the West Midlands. The complexities and techniques of growing these crops on a large scale demand the utmost attention on the part of the grower for weed, pest and disease control.

Such crops on high value soil are high costing and high risk. Farmers cannot afford a failure!

Pest and disease control can be catered for from seed and soil protection to established plant.

Weed competition however is not quite so simple,as weather factors can and do reduce the efficiency of many pre-emergence techniques. Also many herbicides are often too specific in the weed spectrum to give adequate protection if used on their own.

These are some of the factors why farmers need to examine and use programmes of sequential uses of herbicides often outside manufacturers' recommendations.

The specialist merchant advisor in agrochemicals is bombarded at times with problems resulting from inadequate weed control due to weather factors or the narrowness of the weed spectrum.

It is necessary therefore to plan for all the factors of weed control in an intensive situation and because of points mentioned previously sequential use of 2, 3, or more herbicides often from different manufacturers. Whilst specific knowledge is available on some products, inter-reaction can occur with others, particularly with tank mixes. With such mixes chemical incompatibility can arise which precludes further experiments, but often where chemicals are successfully mixed in the tank there is no knowledge of any biological effects.

With some crops however tank mixes of chemicals for a single application are not suitable for long term, broad spectrum, weed control. The farmer therefore looks at and enquires about a series of chemicals recommended for a crop which he can, or thinks he can, use safely as a sequential treatment.

CROPPING AND TECHNIQUES OF GROWING

The most common use of sequential herbicide treatments today is probably on the carrot crop. There are some 10-11 products officially approved for use on carrots. Of these the main ones used are chlorbromuron, linuron, or mono-linuron, metoxuron, prometryne and trifluralin, with certain uses for dalapon and tri-allates.

It is common for many growers to use linuron pre-emergence and when carrots have reached the pencil stage to apply a mixture of chlorbromuron - metoxuron to control emerged knotgrass and mayweed species. The practice of using metoxuron as a sequential treatment in carrots was used by growers four years before a firm recommendation was issued by the manufacturers - how long will it be before metoxuron/chlorbromuron/linuron (perm 2 from 3) can be 'officially' approved or even recommended as 'growers risk'?

Onions

In the case of onions grown as spring sown ware crops, there is a veritable army of herbicides available for both pre and post-emergence use. On close scrutiny nearly all have weaknesses on certain weeds! Sequential use therefore is essential for a grower of large acreages of onions to achieve desired economic weed control and minimise hand labour. It is common to use a mixture of pre-emergence herbicides on this crop such as propachlor + CIPC and to this is sometimes added paraquat at the time of application,to control any small weeds that have emerged prior to the onions.

Subsequent post-emergence may be with pyrazone/chlorbufam at the post-crook stage. Further sequential treatments are with methazole, ioxynil, ioxynil/linuron, aziprotryne and on organic soils cyanazine. Whilst all these herbicides can be used within the terms of reference by the manufacturers,little is known about the synergistic effects or the accumlative effects of a series sprayed one after the other.

Some manufacturers say there is no need to use a 'battery' in this way but practise often proves otherwise because of weather factors or the species of weeds to be controlled.

In brassicaes, parsnips, leeks, and onions sown in August for overwintering, the same problems frequently arise.

Cereals

The techniques in weed control in cereals are beginning to change! Treatments with residual herbicides used originally for wild oat and blackgrass control have shown benefit in controlling broad leaf weeds! Recommendations for winter wheat of tri-allate granules followed by a reduced rate of methabenz/thiazuron has been made by the manufacturer of both products to be applied in the autumn. Should this treatment fail to give control of blackgrass, what effect on the crops will a sequential treatment with isoproturon have,applied in late February or early March?

Winter wheat is often drilled after potatoes. We already have situations where metribuzin would be used on the potatoes and due to weather factors the tolerance factor of the wheat may be borderline. Whereas standard hormone treatments for weed control in April/May the following year may have little or no effect in acting as a synergist to metribuzin, do we know the effect of say 4lbs chlortoluron applied soon after drilling or an application of isoproturon, tri-allate and others applied early in the life of the plant.

In the case of atrazine, used for weed control in maize, levels of one part per million remaining in the soil can cause damage in low rainfall situations. With sequential use of herbicides in following crops, particularly other residuals, serious damage could occur.

Where does the advisor go for soil residue analysis?

Sugar-beet

Weed control in sugar-beet is complex (and that is an understatement)!

Sequential uses in this crop have increased with the necessity to cut labour costs and drill to a stand. This has mainly come about because of inadequate returns on the crop and ranges of herbicides that are too specific or weather affected. Certainly in my opinion and that of many growers, crop tolerance to post-emergence chemicals such as phenmedipham with or without additions of adjuvant oils or barban have been reduced by previous applications of pre-emergent applied herbicides.

Vining-peas

Sequential treatments of this crop is widespread. Tri-allate, eptam, prometryne and cyanazine are all widely used pre-emergence. DNBP and cyanazine are used post-emergence.

In the 1950's due to examinations of sequential use, TCA used pre-drilling was found to reduce the wax on pea leaves and subsequent post-emergent application with DNBP-amine gave considerable scorch.

This problem came to light long before TCA was in widespread use as a pre-drilling treatment of peas to control wild oats and couch grass.

Are we in a similar situation, that we know as much about say cyanazine, used pre-emergent followed by a post-emergent treatment with the same chemical and later because of the need for a clean crop, sequential treatment with DNBP-amine.

Dwarf green beans

In this crop we have a clear instance of joint work and recommendations by two manufacturers. Pre-drilling treatments with trifluralin and post-emergent treatment with bentazone have broadened the weed spectrum and enabled growers to harvest more easily. With new advanced harvest machinery for this crop and vining peas already available, improved weed control measures are vital to enable the grower to achieve optimum plant arrangements and consequently improved yields.

DISCUSSION

The research availability for knowledge of technique is limited and pressures in this field are great. Complication of weather factors make the job of research workers in agriculture more difficult - however does one cope with the drought conditions experienced this year (1976) when so many stress factors would be unknown at the time of planting?

The grower of many vegetables and some other crops is constantly under pressure to produce a farm finished product free of contamination of weed, pest and disease. To enable him to do this he has to examine every chemical and mechanical aid available.

While it is true to say that vegetable crops demand more sequential uses of various herbicides than say cereals, potatoes, dried peas and sugar-beet, nevertheless there is increasing use of such techniques.

The local farm advisor - be it he or she - to whom the farmer turns, must be well informed in depth to be able to cope with all the problems and to give logical, sensible and impartial answers.

The specialist agrochemical merchant or contractor is often the person the farmer will approach.

Who is he to turn to in case of need? The manufacturer - ADAS - WRC or other branches of the ARC such as NVRS?

Or why does not the farmer himself ask such people?

The manufacturer is better able to give advice on the product he sells but if asked about mixing or sequential use with other manufacturers products he often does not want to know. (There are a few exceptions).

ADAS can only recommend within the scope of the approved products book or various short term leaflets. WRC and NVRS follow similar procedures but in some cases can be more forthcoming in personal discussion.

I believe that the person closest to the farmer and in the best position to give advice in this respect, is specialist advisors in agrochemicals in the distribution and contractors trade.

It is essential that such distributor companies are fully informed by manufacturers of extended technical work on products - inter-reaction of subsequent treatment with either their own or other firms' products. It is necessary for the specialist distributor to feed back to manufacturers information gathered and to establish a closer liaison to do this.

So many herbicides are complementary to one another and not necessarily competitive.

Sequential treatments in many crops will increase as labour cost and availability arise, let alone increased mechanisation in planting and harvesting techniques.

No one section of the crop protection industry is solely responsible but I think manufacturers could do more - they have the most to gain! WRC and NVRS could do more in specific crops. ADAS is limited because of money - plus the fact that in many cases the field officer, who closest to the farmer has to be 'jack of all trades and master of many'.

Processors and Growers Research Organisation at Thournaugh, Nr.Peterborough is a private research establishment. At such centres practical relevant advice in sequential treatments can be discussed within the scope of their crop types.

Should such units get government aid for work on sequential treatments? Also private units of this type may be more acceptable to manufacturers who wish to co-operate privately in the early stages of sequential programme development.

Is there a need for more private units of this type? If so who is to pay for them?

Apart from the need for a broader knowledge of sequential treatments from the crop production angle, what about the safety factors? At the moment there is little heed taken by PSPS of sequential treatments in respect of the user or the consumer! As I said earlier, sequential treatments will continue to gain popularity. It is no good PSPS having a selfrightous attitude over this and shutting their eyes, hoping the problem will go away. They have a duty to look at and inform practically on this problem!

Progressive farmers have long been ingenious in adapting machinery to suit their particular needs. They have the same talent in adapting herbicides to their farming systems and techniques of growing. It is essential that sound guidance be given to such farmers on a broad basis within the approvals framework.

No one manufacturer alone is in a position to do this and the farmer does not want to deal with a dozen people.

The obvious person with the knowledge to do this work is the specialist agrochemical advisor.

Proceedings 1976 British Crop Protection Conference - Weeds

TANK MIX PROBLEMS FOR ADVISORS AND USERS

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Summary In spite of the considerable amount of work that has been carried out by manufacturers to combine various active chemicals into ready made cocktail formulations, the environment in which we operate always seems to outsmart us, and present us with new problems whose obvious solution is yet another new combination or formulations.

In the past these mixtures have often started as tank mixes, made with fingers crossed and little consideration for chemistry!

Unfortunately such field mix performances are rarely recorded, and even more rarely published, so that information is limited and not very reliable.

Advisors' problems are therefore not only continuous, but recurring and increasingly complex.

Users' have the same problems of chemistry, toxicology and phytotoxicity, plus that of insurance, and the risk of increasingly restrictive legislation should disasters result.

All these problems should be, but rarely are, weighed against the convenience of a one pass spray programme target.

The general increase in interest in tank mixing that has occurred over the last few years has a variety of coinciding causes.

The farmer gains much from the obvious savings, in application time, expense, and wheelings, but additionally mixes of 1 + 1 often equal 3 in terms of product efficiency.

This gives additional incentive to the practice on the farms, and encourages manufacturers' interest as well.

The economics of expensive chemicals can often be very much improved by partial substitution of cheaper material, which brings down the total cost per acre.

Similarly, the increasing costs of research make it essential for manufacturers to explore every avenue of exploitation once they have a new product, and tank mixing is an increasingly useful avenue for exploration and exploitation.

As a spraying contractor one's interest should be directed toward discouraging tank mixes, in order to increase the number of applications from which one's living is made, but life is not that simple, and one's interests are best served by aiming at giving maximum value for the customer's money.

There is clearly a general appetite for tank mixtures therefore, but there is currently very little in the way of a recipe book.

In the past, manufacturers were not at all keen to be involved in advising, learning, or even admitting the possibility, of tank mixing, so users stumbled along finding out the hard way, and dragging industry along behind them!

Memories of early mixing attempts that achieved jellies, dead crops, thriving weeds, and various other horrors, encourage caution and illustrate some of the pitfalls. For example, when we first mixed D.N.O.C., with M.C.P.A., to control broad leafed weeds and thistles in one operation, we obtained, result failures because the scorch of thistle leaves by D.N.O.C., prevented the M.C.P.A., from performing satisfactorily.

This simple mixture illustrated the benefits as well as the failings of mixtures however, because the control of the broad leafed weeds was much enhanced by the presence of the M.C.P.A.

At the same time we saw the need for care in tank mixing methods, because the addition of the M.C.P.A., before the D.N.O.C., was thoroughly agitated, produced a gloriously sticky jelly in the filters.

Little wonder that my colleagues at Fisons tut-tutted when reckless competitors began to mix basics in the drum, a few years later!

They soon caught on to the 1 + 1 = 3 idea however, and mix it with the best of them now!

The situation has changed completely now, and we all seem to be floundering along together through the many problems and pitfalls.

All too often of course, lack of forethought causes the user to call in the advisor at the very last moment and present him with the problem, the proposed mixture, the tractor driver, a machine loaded with water, and three minutes for decision making.

Many of the mixtures now being manufactured as such, started life as reactions to similar problems in field situations that more or less because of the immediate nature of their problems demanded something new, so we should not be put off.

Advisors and farmers still tend to try new mixes on a large scale (the whole crop), when there is only the pressure of expediency to lead them on, and this is unnecessarily brave of them.

Advisors sometimes forget that if it all goes awry the blame will be their's exclusively!

The problems will become rapidly more complicated as new chemicals come forward, and even new formulations of established chemicals complicate accepted practice. One of the basic problems of course, is not of chemical compatibility, but of user attitudes!

Rather than spend money on a more efficient sprayer, or a good contractor, the user prefers to gamble on cutting corners, and the advisor is often led into the same habits. At worst, an extra application cost is £5 per hectare, which cannot possibly constitute a fair risk to take. Any gambler worth his salt would risk £5 to gain £1,000, but the man who risks £1,000 to save £5 has a problem that is more appropriate to the mental hospital than the British Crop Protection Council!

Some information exists already thanks to Manufacturers lists and leaflets, but it is still rather grudgingly offered.

Campatibility charts are available, although these are normally, and properly, hedged about with conditions, and suggestions to make the unwary more careful.

The Herbicide Compatibility Chart for 1976, published by Meister Publishing Company of Willoughby, Ohio, is one of many, but it is particularly good in its preamble, which I can do no better than reproduce:

> " The 1976 compatibility chart is for preliminary planning -- <u>not</u> a guide for use. Follow manufacturers' directions. In the actual application of sprays and the use of chemicals and other materials, exclusive reliance must be placed upon use directions supplied by the manufacturer. The compatibility indicated herein is not intended to refer to residues or residue tolerances.
> Read the label. Meister Publishing Co., has relied upon information supplied by various manufacturers and state agricultural authorities.
> Certain solvents and emulsifying agents (i.e. different formulations) may change the compatibility. For instance, the addition of an emulsifiable insecticide or extra surfactant to a herbicide may so alter the wetting properties of the mixture as to reduce selectivity and cause crop injury.
> Weather, soil, and moisture conditions may affect phytotoxicity.
> Follow the directions of the manufacturer or your State agricultural extension agents or advisors.

Generally speaking there may be less problems mixing similar formulations. If mixing powders and liquids, it may be helpful to add the wettable powder to a partially filled tank and add the emulsifiable formulation last. Prior to mixing a tankload of any herbicide combination or herbicide/liquid fertilizer combination, it is recommended that physical compatibility be checked using a test such as the one outlined in the box above left.
Always follow directions on the product labels and other available information supplied by the manufacturer. References to products of a particular manufacturer in compatibility chart are not to be construed as an endorsement or certification by Meister Publishing Co. that it has inspected or tested and approves of such product or that it has tested or verified the compatibilities set forth herein."

Apart from the cross reference of chemicals, whose general compatibilities are indicated by a three colour indication there are twenty numerical indicators detailing less general features. There is also a useful description of a simple field test to indicate the most crude symptoms of incompatibility in the proposed combination. If such a crude mix test is carried out as soon as the problem becomes apparent, there can sometimes be a day or two to observe results before passing to the next obvious stage of treating a small part of the crop a few days before the whole operation is undertaken.

Most farmers are able to forecast their weed problems well before the event, but unfortunately they do not in many cases plan their chemical applications and pre-crop cultivations to meet the forecast problems.

This emergency situation is more common in the case of insecticides and fungicides, because those particular pests always arrive unexpectedly, even every year!

Unless users do plan, regulations will obviously be made, which will push up research expenses still further.

Eventually, with our small markets the costs of research will put all our crops into the small acreage crop category to be discussed by Peter Birch.

Not enough is done to encourage advisors and users to make records for themselves, let alone make the fruits of their ingenuity available to others. Perhaps they consider that some of the things that are done are so hair-raising that they should remain as treasured, or forgotten secrets!

What we need is someone to write to about it all. A Pesticidal Lancet!

The seriousness of the lack of information is shown by the report and recommendations from the working party set up by B.C.P.C., under the Chairmanship of Mr. R.F. Norman to consider among other things, the holding of a symposium on the compatibility of pesticides. The recommendation on this subject was: " That there is no case for holding a symposium on the broad subject of compatibility of pesticides etc., (as per Terms of Reference), due to lack of quantitative data."

A sorry situation after all the years of experience in the field.

The rest of the recommendations were more positive and optimistic so they are included as an appendix to this paper as possible answers to some of the problems.

If the scientific establishment were a little less toffee nosed about the quality of data coming forward, there would be a great many more reports from individuals, who may at least indicate worthwhile areas for more thorough investigation on a higher scientific plane.

If those associations that contribute annually to the symposium on chemical usage over the previous year, were to encourage their members to report throughout the year, we should all profit. The information could be passed on to B.C.P.C., either piecemeal or as a whole in time for the symposium.

Failure to take voluntary action will produce further crop losses and possibly worse, resulting in the same degree of over-regulation here as exists in the U.S.A., where field experiments outside label recommendations are not permitted!

Advisory teams can be rapidly transformed by changing regulations from the helpful, broadminded approach, to which we have become accustomed with A.D.A.S. in this country, to legally bound narrow minded upholders of the rule book. We have seen this in the Ministry of Agriculture Safety Inspectorate, where numbers have increased enormously, doubling in the last twelve months, unfortunately at the expense of the Advisory Service whose numbers have been decreased. The role of these people has changed to one of policing the laws rather than helping users, and now in fact they have been removed from the Ministry of Agriculture to the Health and Safety at Work Executive to complete the transition. All this as a result of changing a simple Code of Conduct into legal requirements. Having lost their last humanizing advisory function, this plain clothes police body, which will soon outnumber users as well as advisors, will need additional crimes to chase, so advisors and users must keep clear of disasters that could bring about restrictive legalisation of such happy and successful arrangements as the Voluntary Approvals Scheme for example. The National Association of Agricultural Contractors is receiving ever increasing cries for help from members whose men, having perfectly good drinking flasks, have not used their bottles, clearly labelled DRINKING WATER. What a pity if the members were suddenly taken to court, because they had taken seriously the farmers instruction to " Chuck a little of that other stuff in Charlie".

All these hazards lie in wait in addition to the practical field problems faced by advisors and users, but too often they are forgotten when the pressures are on to save a pound or two. This urgency is understandable perhaps for the user, but the short term responsibility is on advisors to face up to the worst problem of all, and tell the user to get on with two applications rather than one.

The longer term depends upon the will of the Industry to collect and redistribute the wealth of useful information!

Such an operation could create a landmark in the Industry's forward progress!

APPENDIX I

BRITISH CROP PROTECTION COUNCIL

WORKING PARTY ON COMPATIBILITY.

The Working Party recommends to Council;

1. That there is no case for holding a symposium on the broad subject of compatibility of pesticides etc. (as per Terms of Reference), due to lack of quantitative data.

2. That consideration be given to a closed scientifically based symposium in relation to compatibility of pesticides and other chemicals in fruit production.

3. That problems of sequential and repeat treatments should be more formally taken account of in the Annual Reviews held under the auspices of Council.

4. That ADAS and Council sponsering organisations should monitor and report on enquiries relating to compatibility at the Annual Reviews.

5. That a chapter relating to mixtures etc. be included in the Weed Control and Insecticide and Fungicide Handbooks and the Approval Booklet.

6. That the definitions recommended by it are adopted as standard by the Council for its conferences and publications.

7. That the MAFF Pesticide Usage Surveys are more widely publicised through, for example, the Council's publications and company literature.

8. That a similar Working Party be convened in approximately three years time or earlier if enough data warrants it.

NOTE: In this paper the term Annual Reviews refers to the Herbicide and Insecticide and Fungicide Meetings held under the auspices of Council.

(EDITORIAL NOTE: these recommendations form part of an unpublished report from the Working Party to the British Crop Protection Council in April 1975.)

Proceedings 13th British Weed Control Conference (1976)

CLEARANCE OF HERBICIDES FOR

MINOR USE RECOMMENDATIONS

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Summary The importance of the minor uses of herbicides is evaluated and the problems of Clearance are outlined. Various proposals as to how these problems can be overcome are put forward and the importance of Clearance with regards to the safety of man and the environment are stressed.

Resume L'importance des utilisations mineures des herbicides est évaluée et les problèmes d'élimination sont exposés à grands traits. Des propositions variées pour comment surmonter ces problémes sont proposées et l'importance de l'élimination en ce qui concerne la surêté de l'homme et l'environnement s'accentue.

INTRODUCTION

By the economic nature of things, herbicides are initially developed for major uses. With a company having to foot a development bill of £4 million and 7 years' testing, only a large scale use can pay the bill.

Although herbicides cannot be primarily evolved for minor uses it can be discovered during the trial work that an important minor use exists. This may be for the control of an important weed in a small acreage crop (speedwell in chicory) or a not so important weed in a large acreage crop (horsetails in cereals).

On the surface it would appear that to bother about such uses would be commercially unsound. However, minor uses can be important from the farmer's, manufacturer's, advisor's and the nation's point of view.

IMPORTANCE OF MINOR USES

1. The Farmer/Grower

A farmer's or grower's capital may be tied up in a minor crop or a major crop may be threatened by a problem which is nationally of minor significance. On courgette marrows the absence of a suitable herbicide is costing growers at least £20 per acre, although to put the problem into perspective on a national basis, on a total 230 acres the total value is only £4,600 if growers hand weed instead of using chemicals as estimated by Whitwell (1974).

2. The Manufacturer

For the chemical manufacturer, today's minor use can soon develop into tomorrow's major use. For example it was only a few years ago that the use of carbetamide, dalapon and propyzamide in oilseed rape were considered minor uses but today with increased acreage they are now major uses. Who knows what will happen to lupins tomorrow? Minor uses may also give an indication of potential major uses. Thus, propyzamide was originally developed for use in a relatively minor crop, lettuce, but is now recommended for use in 5 major crops, including forestry.

3. The Advisor

On the advisory side minor uses can take up a disproportionate amount of time. It is particularly important to the advisor that minor uses are cleared because he can be sorely tempted to make a recommendation for a use which he knows will overcome a particular problem, but may not be cleared for this purpose.

4. The Nation

Nationally, minor uses can obviously be of great importance and here an example of the use of insecticides can best illustrate the point, for no one would doubt that a pest such as Colarado Beetle could become a major problem if it were not for the minor use of insecticides for controlling the very rare outbreaks that do occur and would otherwise spread rapidly.

CLEARANCE PROCEDURE

Once the new use has been assessed then clearance must be sought. "Clearance" here concerns the passing of pesticides under the Pesticides Safety Precautions Scheme (PSPS) as agreed between Government Departments & Industry (Revised March 1971) for use in agriculture, horticulture, forestry, home gardening or food storage in the United Kingdom (England, Wales, Scotland & Northern Ireland). Such pesticides are passed or "cleared" under The Scheme with a view to ensuring the safety of the user, consumer, any member of the public, livestock, domestic animals and wildlife. The Scheme is not concerned with effectiveness of products; this comes under the Agricultural Chemicals Approval Scheme.

The PSPS applies to all active ingredients formulated as pesticides, that is insecticides, fungicides, rodenticides, plant growth regulators as well as herbicides. In addition to new products The Scheme covers:

(i) Any extension of the use of an existing pesticides.

(ii) Any product containing an active ingredient which, although not new, is in a new formulation, or is used in a new way (such as new methods of application) which could produce a new or increased risk to the user or consumer.

Although PSPS does not apply to the clearance of products overseas, the problems encountered with regards to minor uses as discussed in this paper may well apply to such situations. There are various stages of clearance which a product must go through before it is generally available on the market. The restrictions which are imposed and the data required at each stage will depend upon the particular product, but the summary in table 1 outlines the general situation.

PROBLEMS OF CLEARING MINOR USES

The question must now be asked, why haven't products been cleared under PSPS for ALL the minor uses that have been discovered? There appear to be 3 answers to this question

a. Time

It is quite natural that once the minor use for a product has been defined, those concerned may wish to get it cleared as quickly as possible. However, delays are inevitable. It may take several years from Limited Clearance to Commercial Clearance (Table I) to the launching of a new product for a major use. During this period other research workers, farmers, growers & merchants may know of its existance and wonder why work is not being done on the minor uses. However, the fact must be realised that the manufacturer has to give priority to clearing the major uses because if he fails in this task the product will never be marketed anyway. The manufacturer also faces a dilemma at this stage because if he encourages other people to develop the minor use of a product he may subsequently have to tell them it has been dropped for reasons beyond his control (it may be phytotoxic, or carcinogenic or taint produce etc).

On established products, delays can also occur not because of the processing of notifications by PSPS but because of the chemical need to obtain the necessary plant residue data, and in the case of processed products taint tests may also be required. Analytical equipment required to assess residues may also be committed to analysing newer products and analytical techniques may have changed for which new apparatus is required.

Once a minor use is Commercially Cleared, it may take a year or more for the existing stocks of the product to be used up before the new additional use can appear on the label of new stock.

b. Costs

There are many instances where manufacturers have foot the bill for clearing minor uses when the return to them does not justify the expense. However, there must come a point for some products when such expense cannot be borne and we may here be considering costs of £1000s. These expenses can be particularly high for clearance in edible crops which do not belong to the same family of plants on which clearance has already been given.

c. Misunderstandings

There have been a number of genuine misunderstandings about clearance for minor uses. It is often wrongly assumed, for instance, that because of the inevitable delays in obtaining clearance for reasons already mentioned, the manufacturers are not pursuing the matter. However, it invariably turns out that the process of clearance is being gone through but the time element is not appreciated by the anxious enquirer. In other cases, a product may not be recommended for toxicological reasons or phytotoxicity, say, but it is assumed that the recommendation is being held up because of failure to apply for clearance. The assumption is also sometimes made that because a product is not approved under ACAO it is also not cleared under PSPS.

A misunderstanding that should perhaps be cleared up here is the belief that many minor uses still require to be cleared. The fact is that manufacturers have cleared and make label recommendations for the vast majority of minor uses. For example, clearance of lenacil for mint and chrysanthemums, linuron for parsley, dalapon for kohl rabi, cyanazine for leeks, simazine for asparagus, chlorpropham for spinach and dahlias, chlorthiamid for privet, to name but a few, has not occurred by accident.

PROPOSED SOLUTIONS TO MINOR USE CLEARANCE PROBLEMS

Delays in obtaining clearance, whether it be for major or minor uses, will always be inevitable, but it must be accepted that there will often be a longer delay for clearance of minor uses of new products because of the economic need to clear the major use first. However, the delays could be minimised by informing the manufacturer of the possible minor use as early in the life of the product as possible so that data or equipment being used for the major use can also be used for clearing the minor uses. Clearance is more likely to be actively pursued by the manufacturer if properly presented evidence for the minor use is made and well organised trials are planned to evaluate phytotoxicity, efficiency etc. A manufacturer can put the reputation of his major product at risk if subsequent minor usage shows it to be unsuitable, so he naturally wants to see the latter properly tested.

On the problem of costs, if these are unduly high for the manufacturer to meet, then consideration could be given to cost-sharing. It would probably be difficult for the Ministry of Agriculture to directly contribute to the costs because it may be felt that a government department could end up helping one company more than another. However, a group of farmers/growers or even the NFU on behalf of its members, might finance such work and ADAS could help towards the costs by providing facilities, either in the laboratory or in the field.

Concerning misunderstandings, these can only be overcome by a greater awareness of the procedures for clearance and by ensuring close contacts between the various organisations involved. Fortunately contacts between the manufacturers, farmers/growers and government is closer than it has ever been and it is to be hoped that this will eliminate misunderstandings that have occurred in the past. On the manufacturers side, I would ask that they keep outside parties fully informed as to the reasons for the inevitable delays that occur.

For the future we have EEC regulations to contend with. Hopefully they could ease the clearance problems in that analytical techniques and levels of acceptance of residues are standardised, although it is understood that in the context of present negotiations it seems highly unlikely that residue data from one country will be accepted in support of a notification in another country.

Finally, in the pursuit of clearance for minor uses we must not lose sight of the objectives of the Clearance Scheme which is to ensure the safe use of chemicals. A minor use can pose just as great a hazard to man & his environment as a major use and it is this fact that the manufacturer and PSPS must, and do, consider above everything else.

Table 1.

Summary of stages leading upto Commercial Clearance

	Stage 1 Trials Clearance	Stage 2 Limited Clearance	Stage 3 Provisional Commercial Clearance	Stage 4 Commercial Clearance
For how long is the formulated chemical given clearance?	1 season	1 season	1, 2 or 3 years	Indefinite but can be reviewed
Who can apply it?	Research workers	Agricultural workers/ Research workers	Agricultural workers	Agricultural workers
Can the produce be sold?	No	Yes - in limited quantities and may be required to record to whom it is sold	Yes	Yes
Can edible produce be sold?	Usually no, unless abundant residue data available	Yes if residue data satisfactory	Yes	Yes
Must information be gathered on:				
(i) Operator experience?	Yes	Yes		No
(ii) Wild life?	Yes	Yes	Yes if insufficient data submitted @ stages 1 and 2	No
(iii) Toxicology?	Yes	Yes		No
(iv) Residues?	Yes	Yes		No
Must a label recommendation for the use of the product be made?	No	Yes - if sold	Yes - if sold	Yes - if sold

References

Ministry of Agriculture, Fisheries and Food. Pesticides Safety Precaution Scheme Agreed Between Government Departments and Industry (Revised March 1971).

WHITWELL, J.D. (1974) Problems of herbicide usage on minor crops. Proceedings of the 12th British Weed Control Conference., 1185-1192.

THE CONTROL OF WILD OATS (AVENA SPP) IN RYEGRASS HERBAGE SEED CROPS

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Summary A comparison was made of a range of herbicides for the control of Wild oats (Avena species) in ryegrass herbage seed crops. No herbicide gave a satisfactory degree of control.

There were inconsistent effects on yield.

No herbicide markedly affected the germination or 1000 seed weight of the crop.

Some evidence was obtained to show that benzoylprop-ethyl reduced the size of the harvested wild oat seed, thus increasing the possibility of herbage seed contamination.

INTRODUCTION

Although most herbage seed crops are grown on soils with little or no infestation, certain areas of the country have a serious wild oat problem.

The acceptance of Common Market directives has meant a considerable tightening up of standards for Wild oats in herbage seed at both Higher Voluntary Standard and minimum EEC Grade. The maximum content is now 1 Wild oat seed in 300 g of herbage seed.

The introduction of a wide range of post emergence herbicides for control of Wild oats in cereals raised the question whether these could be used in Ryegrass seed crops. A selection of these herbicides was compared with ethofumesate in a series (AG 14) of ADAS Agronomy Department Experiments from 1974 to 1976.

Ethofumesate has subsequently been recommended, at 10 litres/ha, for Wild oat control in Ryegrass seed crops.

The series was continued over three years and data are presented for 8 sites.

Table 1

Site Details

	Site			Crop	Cultivar
1974	1	Wymeswold	Leicestershire	Lema	IRG
	2	Stragglesthorpe	Kesteven	S 24	PRG
	3	Sherborne	Dorset	RVP	IRG
	4	Sutton Scotney	Hampshire	Gremie	PRG
1975	5	Mollington	Oxfordshire	Combita	IRG
	6	Bretby	Derbyshire	Sabalan	Tet. IRG
	7	Rowston	Lincolnshire	Reveille	Tet. PRG
1976	8	Mollington	Oxfordshire	Combita	IRG

Table 2

Herbicides Used

Treatment	Chemical Name	Rate (kg ai/ha)	Product Name
A	Difenzoquat	1.00	Avenge
B	Benzoylprop-ethyl	1.12	Suffix
C	Chlorfenprop-methyl	4.76	Bidisin
D	Flamprop-isopropyl	1.00	Barnon
E	Ethofumesate	1.68 (1.96 at site 8)	Nortron
F	Flamprop-methyl	0.525	Mataven
G	Control	no treatment	

At sites 1, 3, 4, 6 and 7 some herbicides were applied on two dates, the first to coincide with the onset of active spring growth of the crop and the second 2-4 weeks later. Data for the two dates of application are presented separately where the effect varied markedly.

RESULTS

Results are presented for Wild oat numbers at harvest, crop yields at sites 1, 2, 3 and 8, germination and 1,000 seed weight of the grass seed and size of Wild oat seed at harvest.

Table 3

Wild Oat - Percentage Control

Year	1974							1975				1976	Mean	
Site	1		3		4		5	6		7		8		
Treatments	E	L	E	L	E	L		E	L	E	L		E	L
A	75	50	95	97	14	60	51	78	100	79	79	76	67	77
B	50	75	68	94	20	60	22	-	98	-	86	83	49	83
C	100	nil	61	57	0	49	-	31	-	36	-	-	46	35
D	50	75	23	95	83	83	61	nil	86	93	86	84	52	85
E	100	50	83	7	89	94	97	22	-	79	-	79	77	50
F	-	-	-	-	-	98	72	-	-	-	-	80	-	84
G Control population/m^2	5 plants		21 panicles		(21)		(34)	(0.5)		(0.14)		(107)		

Figures in brackets = panicles

E = early date of application of herbicide
L = later date of application of herbicide

Treatment E in 1976 was 10 litre/ha product

Yield data are presented for four sites showing total yield for sites 1, 2 and 3 and yield of cleaned seed at site 8.

Table 4

Yield of Herbage Seed (kg/ha)

Year	1974						1976
Site	1		2		3		8
Treatment	E	L	E	L	E	L	
A	936	1231	1044	1235	2183	2045	296
B	1201	1301	992	849	2195	2233	356
C	944	1485	1130	1324	2057	2233	-
D	1167	1197	-	1276	1932	2283	265
E	1128	1438	1241	1325	2107	1731	409
F	-	-	-	-	-	-	307
G	1277		1245		1994		305
SE means	± 79		±112		±129		na

The crop at site 8 was very low yielding due to a combination of late grazing and the subsequent drought.

The effect of herbicides on germination and 1,000 seed weight of the crop

Analyses were carried out by the Official Seed Testing Station, Cambridge.

Table 5

Germination percentage

Site	1	2	5	6	7	8
Treatment						
A	74	88	91	97	No treatment effects	No treatment effects
B	78	90	88	99		
C	78	88	92	-		
D	81	87	86	99		
E	82	83	89	98		
F	-	-	86	99		
G	78	89	87	98	93	95

Table 6

1,000 Seed weight (g)

Site	1	2	6	7	8
Treatment					
A	1.83	1.79	2.74	No treatment effects	No treatment effects
B	1.84	1.80	2.69		
C	1.86	1.88	-		
D	1.93	1.89	2.62		
E	1.86	1.86	2.60		
F	-	-	2.62		
G	1.90	1.82	2.48	3.90	3.50

Table 7

The effect of herbicides on the size of wild oat seeds harvested

	Seed Size %>9 mm				
Site	2	5	7	9	Mean
Treatment					
A	97	89	84	76	87
B	84	75	83	63	76
C	99	83	87	-	90
D	98	85	90	73	87
E	96	100	85	83	91
F	-	100	-	65	83
G	97	93	86	81	89

DISCUSSION

The inclusion of ethofumesate at the dose and dates of application shown does not coincide with the manufacturers recommendations. All other herbicides were applied at a date or stage of growth of the crop suggested by the manufacturers.

None of the herbicides gave a satisfactory degree of control. However, flamprop-isopropyl, flamprop-methyl and benzoylprop-ethyl gave reasonable (80-90%) levels of control as did ethofumesate considering that this herbicide was not applied at the date or dose suggested by the manufacturer.

There appeared to be no treatment effects on the germination or 1,000 seed weight of the herbage seed.

Contamination of seed by Wild oats is a serious problem. With large numbers of Wild oats seeds in the harvested crop wastage of seed due to cleaning up to Certification Standards can be high. The problem is greatest with the large seeded tetraploid ryegrasses. In order to determine the effects of herbicides on the size of the Wild oat seed remaining at harvest, samples were measured and divided into those greater or less than 9 mm. This length was taken as the dividing line between those seeds which could be cleaned out of a ryegrass seed sample and those which could not. However, the critical size is likely to vary according to seed lot. It would appear (Table 7) that benzoylprop-ethyl reduces the proportion of large Wild oat seed thus increasing the problems of cleaning.